SMALLHOLDER INTERCROPPING UNDER COCONUTS IN TONGA
An Analysis Using MULBUD

By

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ABSTRACT

In the national economy of Tonga the contribution of smallholder farmers is extremely important. The smallholders control most of the land and labour resources and generate most of the export earnings. Recent trends show a fluctuation in the export earnings of individual crops but for agriculture as a whole, export earnings remain at around 90 per cent of total exports. There is also a migration of potential agricultural workers to the main island, Tongatapu, and overseas. In this study, different intercropping models are investigated as to their potential for increasing income, employment opportunities and fulfilling subsistence requirements of farm families.

The potentials for intercropping in Tonga are considered by reviewing studies on the advantages of intercropping thereby establishing the technical basis for this type of cropping system. Alternative techniques that can be adopted for the analysis of the intercropping system are also reviewed. Then the MULBUD technique is outlined and adopted for subsequent analysis. MULBUD was found suitable for the analysis as the results were of a comparative nature rather than of optimising nature. In summary the MULBUD technique reports the return in terms of the Sum of Net Present Value (SNPV), amortized value and SNPV per labour day at a specified discount rate. The labour requirements for individual crops, as well as alternative models, are also reported.

The details of individual crop price, input costs, output and labour requirements are considered before establishing the cash flows for individual crops. The cash flows are compared in terms of their SNPV, amortized value, labour requirements and production costs. The assumptions for modelling are specified before comparing different intercropping models

in terms of their economic returns and labour requirements. The financing of cash requirements during the establishment periods, especially of perennial crops, is through loans.

Attention is also directed at the intermediate period in the life of the coconut stand under which there is no or limited potential for intercropping. Therefore the importance of adopting alternative densities to allow for continuous intercropping is also considered. The alternative adopted was found to have higher economic returns.

For the perennial crops, the vanilla intercrop gives the best economic returns followed by the kava intercrop. Bananas are unprofitable intercrops under the present production system. There is little difference in economic returns in the production of the different annual crops. However, the susceptibility of the different crops to changing prices, yields and costs are shown by the sensitivity analysis.

The intercropping system not only can make substantial contribution to the national economy but is also capable of fulfilling the multiple objectives of the smallholder farmers in Tonga.

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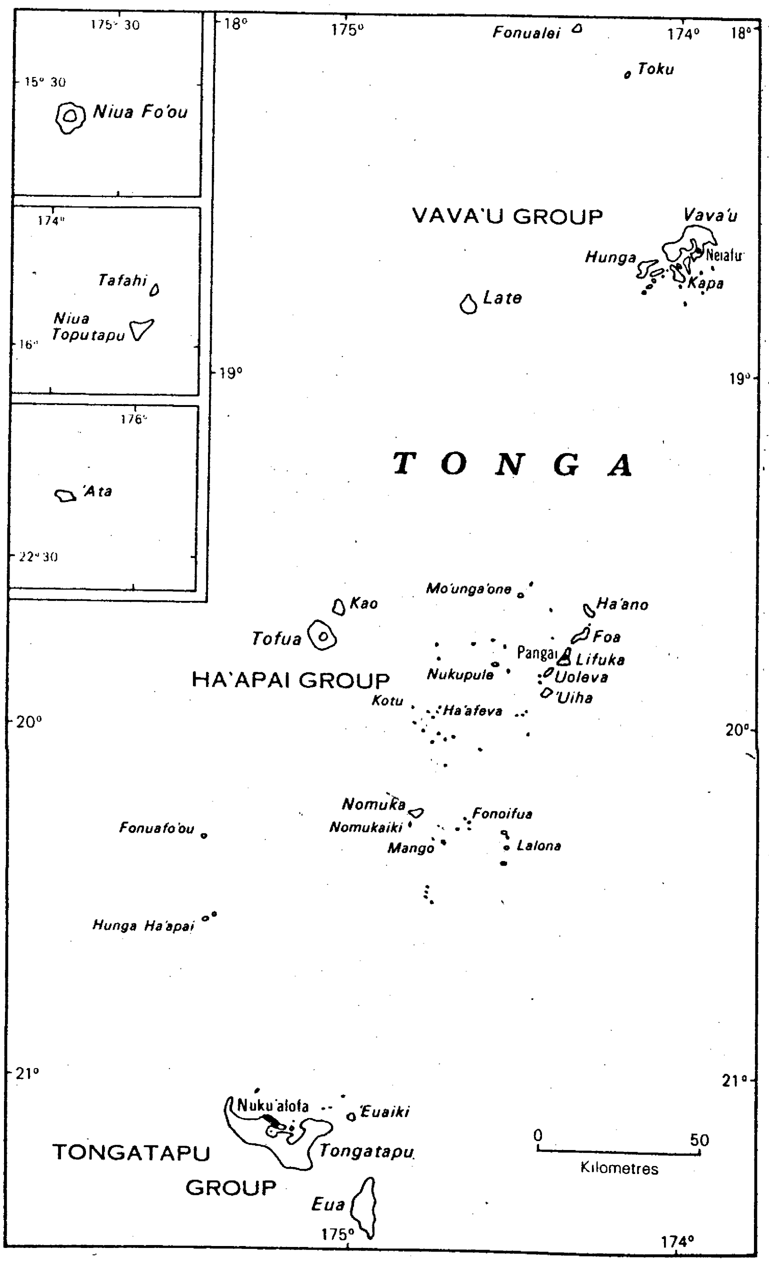
GLOSSARY OF TERMS

Pa'anga	Unit of Tongan currency, the symbol adopted in the study is 'T'. Exchange rate A\$1.00 = T\$0.96 (1981)
Seniti	1 Pa'anga = 100 seniti

MAP OF THE KINGDOM OF TONGA



CHAPTER 1

INTRODUCTION

The economy of the Kingdom of Tonga is primarily based on agricultural production. This is the predominant activity consisting mainly of production of crops for local consumption. Some cash cropping has been added to this subsistence production and this forms the basis for the country's main export earnings.

Cash cropping which includes coconuts, bananas, vanilla, root crops and vegetables contributes to rural family incomes. Apart from this, some members of the families may be employed in either the private or the public sector. Remittances from members who are Zealand, Australia or the United States of America may also contribute substantially to the family income. The growth in the cash earnings is reflected in the desire for a higher standard of living. This is reflected in the type of housing and the number of people who own private vehicles. Earnings from some of the cash crops such as vanilla, xanthosoma and yams have shown an increasing trend. In the case of bananas, export earnings started to increase from 1978. Since 1977, a decreasing trend for coconut products is also observed (Appendix C, Table C.1).

The macro-economic effects of the above situation are an increasing deficit on the trading account. Some of this deficit is reduced by remittances from Tongans living abroad. Other sources of capital includes earnings from services such as tourism and the high level of foreign aid to Tonga. Inflows reduces the deficit considerably.

In this context, this study is concerned with the appraisal of the subsistence sector and its potential for development into semi-commercial agriculture. It is thought that the commercial agricultural sector would provide increasing demand for cash incomes whereas the subsistence sector will continue to provide basic food requirements.

In terms of the whole economy, the agricultural sector should be capable of providing increased export earnings, labour employment opportunities and a stable supply of subsistence food. At the same time the agricultural sector should enable a more effective utilization of the land resource which is becoming a limiting factor and thereby generating surplus suitable for the development of agro-based industries.

1.1 The Resource Base

The resources available to the Kingdom of Tonga are extremely limited. There are no exploitable mineral resources although intensive search has been undertaken. Although the land area is small (Table 1.1), most of it is available for cultivation with the exception of parts of 'Eua, Kao, Tofua and Late. The land which is generally flat or gently undulating is very fertile. Ward and Proctor (1980, p.7) reported the finding of Widdowson (1977) - who stated that:

> "In Tonga, two major deposits of wind blown andesitic volcanic ash mask the surface limestone to a depth of several metres and provide deep fertile soils with good physical properties."

The fertile land together with the favourable climate provides the potential for the development of a highly productive agricultural sector.

It has been estimated that the present consumption of agricultural products and agricultural exports could be supplied from 7 per cent of the available arable land area (Duttaroy, 1980). This estimate signifies the great potential for the expansion of the agricultural sector.

The population is small thus limiting any efficient manufacturing for the domestic market. Any development of the manufacturing sector has to be directed at potential export markets.

TABLE 1.1

DRY LAND AREA AND POPULATION DISTRIBUTION
FOR THE KINGDOM OF TONGA (1976 CENSUS)

Island Group	Area (hectare)	Percentage of Total Area	Population	Percentage of Total Population	Population Density (person per hectare)
Tongatapu	26197	39.2	57411	63.7	2.19
Vava'u	14330	21.4	15068	16.7	1.05
Ha'apai	11930	17.8	10792	12.0	0.90
'Eua	8743	13.1	4486	5.0	0.51
Niuas	3809	5.7	2328	2.6	0.61
Others	1882	2.8	-	-	-
Total	66891	100	90085	100	-

Source: Fourth Five Year Development Plan for the Kingdom of Tonga.

The surrounding sea area, with the Exclusive Economic Zone (EEZ) estimated at 362,600 sq.km., contains an abundance of fish resources. This has a large potential for generating employment opportunities, raising domestic as well as export earnings. Therefore the national income can be increased through the development of both deep sea and inshore fishery.

The main forestry resources, apart from the ubiquitous coconut timber, are on Tofua and 'Eua. Tofua has a potential forest area of 1,600 hectares and 'Eua 1,400 hectares.

Tourism is another important area for development to increase foreign exchange earnings. The growth of tourism was spectacular during the first half of the 1970s but fell off in the second half. The number of tourists arriving in Tonga depends mostly on the number of cruise ships and international flights to Tonga.

1.2 Location

The Kingdom of Tonga covers approximately 360,000 sq.km. of sea area. It includes 169 islands, of which only 36 are inhabited. It is situated between latitude $15^{o}S-23.5^{o}S$ and longtitude $173^{o}W-177^{o}W$. The total dry land area is estimated at 66,891 hectares (Table 1.1). The principal settled areas as recorded in the 1976 population census are presented in Table 1.1.

1.3 Climate

The rainfall is generally very high and well distributed. The monthly average rainfall for the years 1945-1980 is presented in Table 1.2. For the three main island groups, Tongatapu, Vava'u and Ha'apai, the driest month is June with 90mm, 108mm and 73mm, respectively and the wettest month is March with 243mm, 375mm and 303mm, respectively.

The average temperature range recorded between 1949 and 1970 was $17.9^{o}C$ (July) - $29.1^{o}C$ (January). A highest maximum of $31.9^{o}C$ (January) and lowest minimum of $10.6^{o}C$ (July) was also recorded during the period.

The average daily relative humidity for 1962-1973 recorded at the capital, Nuku'alofa, ranges from 67 to 87 per cent.

1.4 Land Tenure

The land is held under a number of different forms of tenure. The most important are the tax allotments, town allotments and leases (Table 1.3).

The allocation of land stems from the land tenure system embodied in the constitution. Under this system, every male Tongan who has reached the age of sixteen is entitled to apply for a rural tax allotment of an area not exceeding 3.34 hectares.

Population growth has led to insufficient supply of suitable land necessary to meet the needs of those eligible for tax allotments. During the censal period 1966-1976 the number of eligible males with allocated tax allotments decreased from 42 per cent to 35 per cent.

TABLE 1.2

AVERAGE RAINFALL FOR 1945-1980

bnth	Tongatapu		Vava'u		Ha'apai	
	Number of Years	Mean Rainfall (mm)	Number of Years	Mean Rainfall (mm)	Number of Years	Mean Rainfall (mm)
Janary	36	209	34	288	34	215
Febuary	36	240	34	253	34	197
Marh	36	243	34	375	34	303
Aprl	36	179	34	217	34	191
May	36	98	32	132	32	94
Jun	36	90	33	108	33	73
Jul	36	97	32	124	32	96
Augst	36	115	31	110	31	104
Sepember	36	134	32	130	32	112
Octber	36	149	32	149	32	110
Novmber	36	131	32	189	32	134
Decmber	36	149	30	213	30	171
Annal Mean	36	1834	32	2295	32	1806

Souce: Duttaroy (1981).

This trend will continue as the population grows. This is a majr problem facing the government as unemployment will tend to increase likwise. A short term solution to this problem is the further subdivsion of the tax allotments into half sizes (1.67 hectares). This was acommodated within the law of Tonga in 1958. Further subdivisions may be iarmful to the economy as less land will be devoted to cash cropping whie most of the land will be used for subsistence crops.

The land tenure system was summed up by Maude (1971, pp.106):

"The system of land tenure which has existed in the Kingdom of Tonga since the late 19th century differs in many respects from those of other parts of the South Pacific,

TABLE 1.3

LAND TENURE 1979

Nature of the Tenure	Approximate Area (ha)	Percentage of Total Area
1) Registered Tax and Town Allotments	31158	41.70
2) Tax and Town Allotments not yet registered but allocated	17035	22.80
3) Hereditary Nobles Estate	5190	6.94
4) Land Leased by:		
(i) Government	698	0.93
(ii) Churches	2032	2.72
(iii) Commodities Board	92	0.12
(iv) Tongan Nationals	664	0.89
(v) Foreigners	1506	2.00
5) Government Lands (uninhabited islands, forest reserves etc.)	8506	11.38
6) Lakes and Internal Waters	2964	3.97
7) Telekitonga and Telekitokelau Reefs - Government	4892	6.55
Total	74737	100

Note: The difference between Table 1.3 and Table 1.2 in area is due to Item 6 and 7 above.

Source: Fourth Five Year Development Plan for the Kingdom of Tonga.

> its two most distinctive features being that land rights are granted solely to individuals and that every tax payer (that is, every male Tongan sixteen years and over) is entitled to 8¼ acres (3.34 hectares) of agricultural land."

1.5 Population

The total population and its distribution as reported in the 1976 census is shown in Table 1.2. The population was estimated to have increased by about 7,000 (8 per cent) during the 1970s. The increase would have been higher resulting in greater social pressures if it had not been for net outward migration to Australia, New Zealand and increasingly to the United States of America.

Equally significant, socially and economically is the drift of the population to Tongatapu. The 1976 census shows that about 11 per cent of the people who live on Tongatapu were born elsewhere in the Kingdom. The situation in Nuku'alofa, the capital, is more pronounced. The population doubled in the 20 year period 1956-1976 of which over 30 per cent have moved in from other parts of the Kingdom.

The average intercensal rate of population growth corresponding to the intercensal years 1946-1956, 1956-1966, 1966-1976 were 3.05 per cent, 3.14 per cent and 1.52 per cent, respectively (Table 1.4). The crude birth rate

TABLE 1.4

THE GROWTH AND STRUCTURE OF THE POPULATION

Category	Population as at Census Date			Estimated
	1956	1966	1976	1980 mid-year
Male (Percentage)	28938 (50.9)	39837 (51.45)	46036 (51.1)	48290 (50.96)
Female (Percentage)	27900 (49.1)	37592 (48.55)	44049 (48.9)	46470 (49.04)
Total	56838	77429	90085	94760
Average Intercensal Rate of Increase	3.05%	3.14%	1.52%	1.41%

Source: Fourth Five Year Development Plan for the Kingdom of Tonga.

decreased from 3.8 per cent in 1966 to 2.8 per cent in 1976. The crude death rate averaged at about 0.3 per cent for both periods (1976 Population Census).

This recent decrease in population growth is due to a marked decrease in the rate of natural increase and an increase in outward migration. The decrease in population growth rate was due mainly to the effective adoption of family planning methods thereby reducing the birth rate. Although data on migration is incomplete it was estimated that during the period 1966-1976 net emigration was equivalent to 0.7 per cent per annum of the population.

The composition of the population by sex has changed only slightly between 1956 and 1976 with the male population composition increasing from 50.9 per cent to 51.1 per cent of the total population (Table 1.4). The population is young with just over 44 per cent under the age of fifteen; 3 per cent is over the age of 65. This leaves 53 per cent as the active population (Table 1.5).

TABLE 1.5

AGE STRUCTURE OF THE POPULATION AS AT CENSUS DATE

Age Group	1956		1966		1976	
	Number	Percentage	Number	Percentage	Number	Percentage
Under 15	24964	43.9	35745	46.2	40038	44.5
15-24	11013	19.4	14044	18.1	18061	20.0
25-34	7953	14.0	9983	12.9	10296	11.4
35-44	5152	9.1	7475	9.7	8519	9.5
45-54	3388	6.0	4775	6.2	6336	7.0
55-64	2244	3.9	2826	3.6	3845	4.3
65 and Over	2124	3.7	2581	3.3	2990	3.3
Total	56838	100	77429	100	90085	100

Source: Fourth Five Year Development Plan for the Kingdom of Tonga.

The economic implications of the above indicates a high potential labour force in the future. However, the migration of the potential labour force from the outer to Tongatapu may cause restrictions in the amount of labour available for agriculture in the outer islands. However, the labour availability for agriculture in Tangatapu is less likely to be a problem. This was reported by Ward and Proctor (1980). Migration to the main island of Tongatapu will also create major problems of increasing unemployment and underemployment.

1.6 Manpower

Manpower comprises that part of the population between the ages of 15 to 64. The manpower is divided into labour force (those currently employed and those actively seeking employment) and that portion which is outside the labour force. In 1976, the portion of the population which was outside the labour force accounted for 27 per cent. This was composed of 19,300 females and 5,000 males (mainly students). Only 23.8 per cent of the total population were in the labour force. Of the total male populatic 39.3 per cent are in the labour force while 7.6 per cent of females are in the labour force (Table 1.6).

TABLE 1.6

MANPOWER AND LABOUR FORCE 1976

	Not in Manpower	Manpower			Total Population
		Outside Labour Force	Labour Force	Total	
Total (000)	43.3	24.3	21.4	45.7	90
Male (000)	23.0	5.0	18.0	23.0	46
Female (000)	21.3	19.3	3.4	22.7	44
Total (percentage)	49.2	27.0	23.8	50.8	100
Male (")	49.9	10.8	39.3	50.1	100
Female(")	48.5	43.9	7.6	51.5	100

Source: Fourth Five Year Development Plan for the Kingdom of Tonga.

1.7 Employment

The share of the labour force in the total population remained constant at about 24 per cent over the period 1956-1976 as shown by Table 1.7.

TABLE 1.7

LABOUR FORCE IN RELATION TO THE TOTAL POPULATION

	1956	1966	1976
Total Labour Force (x 000)	14.3	18.9	21.4
Percentage of Total Population in Labour Force	25.0	24.4	23.8

Source: Fourth Five Year Development Plan for the Kingdom of Tonga.

The 1976 census reported that unemployment of people 15 years of age and over totalled 18,626. Of this, 2,743 (14.7 per cent) were female and 15,833 (85.3 per cent) were male.

Unemployment continues to be a major problem confronting the government. The population and the absolute labour force continues to grow but land is no longer available for distribution to adult males under the terms of the constitution.

The 1976 census revealed that unemployment remains relatively high. The number of unemployed was reported at about 13 per cent of the total labour force. Of particular interest is the high unemployment rate of males in the 15-24 age group which was 28 per cent.

It was estimated in the Fourth Five Year Development Plan for the Kingdom of Tonga (DP IV) that about 4,000 people will enter the labour force during 1980-1985. Of this, over 50 per cent will be accommodated in the agricultural sector. There is inadequate capacity in the monetised non-agricultural sector to provide employment for those who do not own tax allotments.

Due to changes in immigration policies of both New Zealand and Australia and the limitations of wage employment in the monetised non-agricultural sector, it is evident that the most important sector to be considered for increasing employment opportunities, family incomes and foreign exchange earnings is the agricultural sector. Apart from this one of the major potentials for industrial development is based on the processing of agricultural products. Therefore the agricultural sector will be required to increase its output and productivity to provide surpluses for such a development.

1.8 Capital Resources

The capital resources important for the development of a viable commercial agricultural sector includes: (a) the supply of credits and purchased inputs; (b) promotion of extension, research and education; and (c) existence of a suitable infrastructure for servicing transport and market outlets. In this respect Hardaker (1975) pointed out that both capital and skills are scarce in the Kingdom of Tonga.

1.8.1 Infrastructure

Although the infrastructural resources available to the agricultural sector have expanded, some major developments have not been carried out due to lack of capital resources. This is illustrated by the lack of shipping services to promote market opportunities in the outer islands. Marketing opportunities have improved in the main island for most of the agricultural products but to some extent, the outer islands have been neglected. Lack of suitable roads is also a constraint to development, especially for banana production. Shipping remains one of the major problems. Ward and Proctor (1980, pp.178) concluded that:

> "It is clear that both external and internal shipping sectors have significant problems which inhibit agricultural and rural development."

The deterioration in shipping services has been disastrous for the export of perishable crops, such as bananas, root crops and vegetables. This affects small holder production as most crops produced for export are perishable with the exception of coconut products, vanilla (Vanilla fragrans) and Kava (Piper methysticum). Hardaker (1975) also acknowledged that transportation is a problem in Tonga.

1.8.2 Education

Agricultural education in Tonga is taught at the secondary school level. Apart from this, church denominations have established training institutions for school leavers but the enrolment is very limited. Such institutions include Hango and Mahinae'a (Free Wesleyan Church), Niumate (Mormons) and Fualu (Catholic). These institutions teach basic farming techniques at primary level. Tertiary agricultural education has to be attained overseas in colleges such as the Regional College of Tropical Agriculture (Western Samoa), Fiji College of Agriculture (Fiji), Vudal College (Papua New Guinea), and colleges in New Zealand, Australia and the United States. Diploma holders from these colleges are now holding responsible positions in both the government and the private sector. University training for agricultural degrees is also carried out overseas, mainly at the University of the South Pacific (Alafua, Western Samoa) and in New Zealand and Australia. The training of farmers is also done by the Ministry of Agriculture on an ad hoc basis. This training is important because these farmers are almost certain to remain as farmers.

1.8.3 Tonga Development Bank

The establishment of the Tonga Development Bank in 1977 marked a new era for the Tongan farmers. Previously there were no organised formal lending institutions whereby farmers could get loans for crop production. The bank started with a nominal capital of T$250,000.00 and by the end of 1980 this had increased to more than T$1.8 million. Bank lendings have been made for agriculture, fisheries and livestock development. The bank has supported the development of both subsistence and commercial crops. The bank lending is summarised in Table 1.8.

TABLE 1.8

AGRICULTURAL LOAN APPROVAL BY THE
TONGA DEVELOPMENT BANK (T$'000) - 1977-1980

	1977	1978	1979	1980	Total
Beverages and Spices	1.3	8.4	12.5	26.5	48.7
Fruits (Banana, Vanilla)	13.5	27.7	18.6	30.9	90.7
Root Crops	52.6	167.0	106.8	138.8	465.2
Vegetables	21.2	69.0	45.4	46.2	181.8
Others (Mulberry)	1.2	1.3	1.2	0.7	4.4
Livestock	77.2	50.7	31.9	53.1	212.9
Structural	12.8	36.2	21.8	48.4	119.2
Plant and Equipment	36.2	87.6	64.9	30.0	218.7
Transport	19.5	74.1	35.7	125.4	254.7
Communities	-	4.6	1.0	238.8	244.4
Total	235.5	526.6	339.8	738.8	1840.7

Source: Fourth Five Year Development Plan for the Kingdom of Tonga.

About 40 per cent of the loans was provided as working capital for short term crops. The importance of the root crops is reflected by the high percentages of the loan (25 per cent - the highest) attributed to these crops. This reflects the importance of the annual crops for domestic consumption as well as for exports.

1.8.4 Research and Extension

Research and Extension are very important in promoting a subsistence sector into a commercial or partly commercial sector. Effective research must be carried out on existing crops and potential intercrops in terms of increasing productivity and foreign exchange earnings. The results obtained must be transferred to the farmers. This can be done by an effective extension service. These two services are provided by the Ministry of Agriculture, a part of the Tongan public service.

1.9 Imports

In spite of the predominantly agricultural economic base, Tonga is heavily dependent on food imports such as meat, cereals and tinned food. Import items are presented in Table 1.9. Over recent years the foreign exchange earnings from agricultural exports have not kept up with the cost of food imports during the same period. The increase in food import value in recent years reflects the effects of inflation and a rise in the standard of living.

1.10 Balance of Payment

The overall picture for the Balance of Payment for the 1970s shows a growing weakness of the economy (Table 1.10). During the first five years, exports were sufficient to cover only 44 per cent of imports. This fell to 36 per cent during the second five years.

TABLE 1.9

THE STRUCTURE OF IMPORTS (CIF)
BY COMMODITY AND VALUE

Item	1970		1975		1980	
	(T$'000)	%	(T$'000)	%	(T$'000)	%
Food and Live Animals	1621	29.3	3557	27.4	7082	23.5
Beverages and Tobacco	438	7.9	892	6.9	1966	6.5
Crude Materials	185	3.3	1012	7.8	1624	5.4
Mineral Fuels and Lubricants	328	5.9	747	5.8	4293	14.3
Oils, Fats and Chemicals	449	8.1	815	6.3	1727	5.7
Manufactured Goods	1255	22.7	2660	20.5	5986	19.9
Machinery and Transport Equipment	748	13.5	2033	15.7	5095	16.9
Miscellaneous Manufactures	463	8.4	1196	9.2	2230	7.4
Others, Not Classified	52	0.9	51	0.4	131	0.4
Total Imports	5539	100	12963	100	30134	100

Source: Fourth Five Year Development Plan for the Kingdom of Tonga (DP IV).

The major contributor to the current account is unrequited transfers from Tongan nationals living overseas. Throughout the last decade, unrequited transfers were larger than export receipts (DP IV).

The strength of the balance of payments during the 1970s lay in the capital account. The net capital inflow during this period was T$14.5 million resulting in an increase of foreign reserves.

Since the beginning of the 1970s the external position has become more dependent on foreign exchange sources such as unrequited remittances, capital inflow which was predominantly foreign aid, export receipts and tourism which are outside the country's direct control. In

TABLE 1.10

BALANCE OF PAYMENT SUMMARY 1970/71 - 1979/80
(T$'000)

Year	Export	Import	Balance of Trade	Balance of Net Invisible and Transfer Payment	Current Account Payment
1970/71	2377	4601	-2225	1718	-507
1971/72	2426	5587	-3161	1990	-1171
1972/73	2495	5804	-3309	2757	-552
1973/74	3384	7516	-4132	4779	+647
1974/75	5679	13961	-8282	8537	+255
1975/76	3586	12846	-9259	7665	-1594
1976/77	3718	13383	-9666	7932	-1734
1977/78	6722	16369	-9647	9044	-603
1978/79	5132	20012	-14878	12750	-2130
1979/80	10285	25452	-15167	15143	NA

Note: NA Not available.

Source: Fourth Five Year Development Plan for the Kingdom of Tonga.

this respect the structure of the country's balance of payments has weakened although, in terms of foreign reserves and currency strength, the external position appears to be sound.

1.11 The Agricultural Sector in Tonga

The agricultural sector is the most important sector in the economy of the Kingdom of Tonga. Agricultural exports consistently account for about 90 per cent of the total export earnings (Table 1.11). About 70 per cent of the total population depends primarily on agriculture for their livelihood. It was estimated by Duttaroy (1980) that 87 per cent of all households are engaged in some form of farming activity, and 60 per cent of the labour force are engaged in the agricultural sector.

TABLE 1.11

EXPORT BY MAJOR COMMODITIES

(f.o.b. Value - T$'000)

Year	Coconut Products	Bananas	Vegetables, Fruits and Other Agri-cultural Products	Total Agri-culture	Others (including re-export)	Total
1975						
Value	3508	307	448	4326	251	4577
Percentage of Total	77	8	10	95	5	100
1976						
Value	2078	276	673	3026	212	3238
Percentage of Total	64	9	21	93	7	100
1977						
Value	4922	402	830	6153	206	6359
Percentage of Total	77	6	13	97	3	100
1978						
Value	3776	182	575	4533	545	5078
Percentage of Total	74	4	11	89	11	100
1979						
Value	3610	306	857	4773	464	5237
Percentage of Total	69	6	16	91	9	100

Source: Dean (1981).

1.11.1 Size of the Agricultural Sector

The size of the agricultural sector can be estimated by the area cultivated under different crops. Very little information is available in this area; however, some estimate can be made. For example, Duttaroy

(1980) estimates the arable land in terms of tax allotments (3.34 hectares). He estimated that there were about 12,000 tax allotments covering an area of about 40,000 hectares. This is about 60 per cent of the total dry land area.

1.11.2 Importance of the Agricultural Sector

The importance of the agricultural sector to the economy has been discussed previously in terms of its contribution to the foreign exchange earnings. The agricultural sector's importance is also reflected in allocation of government controlled resources, including foreign aid in the Fourth Five Year Development Plan. This is presented in Table 1.12.

TABLE 1.12

ALLOCATION OF GOVERNMENT CONTROLLED RESOURCES

Sector	Percentage Allocation
1) Agriculture	18
2) Forestry	1
3) Fisheries	15
4) Mining and Quarrying	1
5) Manufacturing	3
6) Electricity and Water	7
7) Building and Construction	1
8) Wholesale, Retail, Trade and Tourism	9
9) Transport - Communications	24
10) Services, including Health and Education, Law and Order and Government Administration	21
Total	100

Source: Fourth Five Year Development Plan for the Kingdom of Tonga.

The allocation for the agricultural sector is 18 per cent. Agriculture will also benefit from the allocation to Transport - Communications (24 per cent) in terms of improved raods, more vehicles, wharf facilities and inter-island transports.

1.11.3 The Performance of the Agricultural Sector

The performance of the agricultural sector can be looked at in terms of the domestic production and consumption and the contribution to the Gross Domestic Product (GDP).

1.11.3.1 Household Consumption

Duttaroy (1980) did a survey of the household consumption for the Kingdom of Tonga. The result is presented in Table 1.13. The survey recorded that all consumption of staple subsistence food was met by local production. About 41,755 tonnes of root crops were produced in Tonga in 1979. Of these, 37,313 tonnes were consumed locally, the rest exported.

1.11.3.2 Gross Domestic Product

When studying the Gross Domestic Product of subsistence and semi-subsistence economies, it is always hard to estimate the non-monetary component (Fisk, 1975). However, Table 1.14 reports both monetary and non-monetary contributions which indicate that an attempt has been made in estimating the non-monetary component. The writer is not aware of how this was done.

During the 1970s, there was a marked shift in the structure of production. Although agriculture remained the dominant sector in terms of both output and employment, its share in the total production fell from 50.1 per cent in 1974/75 to 40.5 per cent in 1979/80. The decline was due mainly to a decline in copra production due to fluctuating prices and a severe drought which occurred in 1977. This caused a decrease in agricultural production.

TABLE 1.13

ANNUAL HOUSEHOLD CONSUMPTION OF LOCALLY PRODUCED FOOD AND ANIMAL FEEDS IN METRIC TONS IN 1979

Items	Tongatapu Urban	Tongatapu Rural	Outer Islands	Kingdom of Tonga
Root Crops				
Xanthosoma	1607	4804	4002	10413
Swamp Taro	168	483	361	1012
Cassava	1539	4098	4439	10076
Sweet Potatoes	332	229	259	820
Yams	895	4174	3498	8567
Alocasia (Giant Taro)	174	782	2580	3536
TOTAL ROOT CROPS	4715	14570	15139	34424
Vegetables				
Tomatoes	125	470	186	781
Fruits and Nuts				
Plaintain	368	1673	1623	3664
Banana	469	1952	740	3161
Watermelons	32	187	144	363
Mature Coconuts ('000)	1348	5501	4888	11737
Green Coconuts ('000)	72	1012	1306	2390
Animal Feeds				
Coconuts ('000)	1133	6632	8997	16762
Xanthosoma	266	255	93	614
Cassava	754	1755	2550	5059
Kape etc.	7	68	400	475

Source: Duttaroy (1980).

TABLE 1.14

GROSS DOMESTIC PRODUCT BY KIND
OF ECONOMIC ACTIVITY
(Current Prices - 1981)

	1974/75		1977/78		1979/80	
	Value (T$'000)	%	Value (T$'000)	%	Value (T$'000)	%
1) Agriculture, Forestry & Fishery	10530.6	50.1	12966.3	41.8	15582.4	40.5
a) Monetary	5263.0	25.0	6238.5	20.1	8216.8	21.4
b) Non-Monetary	5267.6	25.1	6727.8	21.7	7365.6	19.1
2) Mining and Quarrying	110.1	0.5	195.3	0.6	260.8	0.7
3) Manufacture	1110.2	5.3	2303.5	7.5	2955.8	7.7
a) Monetary	935.7	4.5	2002.0	6.5	2579.0	6.7
b) Non-Monetary	174.5	0.8	301.1	1.0	376.8	1.0
4) Electricity and Water	196.4	0.9	342.7	1.1	339.5	0.9
5) Construction	761.6	3.6	1497.3	4.8	2462.2	6.4
a) Monetary	480.1	2.3	1288.9	4.2	2152.7	5.6
b) Non-Monetary	281.5	1.3	208.4	0.6	309.5	0.8
6) Wholesale and Retail Trade, Restaurants and Hotels	2822.8	13.8	4439.3	14.3	5507.7	14.3
7) Transport, Services and Communications	775.9	3.7	1824.7	5.9	2519.9	6.6
8) Finance and Real Estate (including ownership of dwellings)	1535.0	7.3	2270.0	7.3	2744.3	7.1
a) Monetary	193.0	0.9	453.0	1.5	632.7	1.6
b) Non-Monetary	1342.0	6.4	1817.0	5.8	2111.6	5.5
9) Community, Social and Personal Services	3171.7	15.2	5188.5	16.7	6089.9	15.8
10) Gross Domestic Product at Factor Cost	21014.3	100	31027.2	100	38462.5	100
11) Plus Indirect Taxes less Subsidies	3817.6		5290.3		6066.6	
12) Gross Domestic Product at Market Prices	24831.9		36317.5		44529.1	

Source: National Account Estimates for the Kingdom of Tonga 1974/75 - 1979/80.

1.12 The Kingdom's Objectives

The Tonga Fourth Five Year Development Plan sets out the long term economic and social objectives of Tonga as follows:

> "Achieve a sustained increase in the production of goods and services, and real incomes of the people;
>
> Achieve effective management of the national economy;
>
> Achieve a fair distribution of goods, services and income between the people in different parts of the Kingdom;
>
> Enhance the quality of life and security of the people, the cultural heritage of the nation, and the preservation of the environment;
>
> Develop harmonious relations and mutual cooperation in economic, social and related spheres with all nations and international organisations."

While there are other sectors that can be considered in achieving part of the national objectives such as an equitable distribution of income, improving the quality of life and increasing production, focus is directed at the agricultural sector. The economy of the country has always evolved around agriculture. The importance of the agricultural sector to the economy of the Kingdom of Tonga is clearly stated in the Fourth Five Year Development Plan. Given the need for new technologies and improved production systems, within the limits of capital and other available resources, the agricultural sector will still be the main sector for development in the future.

1.13 Plan of Study

Agriculture plays an important role in the economy of Tonga. The government is faced with the task of organising agriculture both in the subsistence and commercial sectors. The main issues are raising family income, creating employment, providing food, earning foreign exchange and producing surplus for agro-based industries.

The Fourth Five Year Development Plan sets out targets for existing cash crops such as vanilla, bananas, coconuts, root crops and vegetables. The plan also probes the possibility of introducing new intercrops, with potential markets, to be planted under coconuts.

1.13.1 Objective of the Study

In this study the objective is to examine the economic potential of planned intercropping of coconuts in Tonga and at the same time allowing for social and subsistence obligations of the households. Different intercropping models will be examined and reported upon. The choice of an optimum model will be left to the farmer. Economic data are confined to the financial aspects of the system while social and subsistence obligations are taken into account in the different crop models presented.

Therefore the objective of the study will include the appraisal of different crop models in terms of:

1) Raising farm family income.
2) Net Returns (SNPV).
3) Employment opportunities which are reflected in the labour requirement.
4) Fulfilling subsistence and social requirements.
5) Foreign exchange earnings.

The next chapter will look at the existing farming system in Tonga. It considers intercropping as one type of production system to fulfil some of the nation's aspirations. A review of literature with regards to intercropping will also be carried out.

CHAPTER 2

AGRICULTURE AND POTENTIAL FOR INTERCROPPING

This chapter will discuss firstly the traditional farming system in Tonga focusing on the existing cropping pattern. Secondly, there is a discussion of the importance of the technical and agronomic aspects of intercropping thereby establishing the need for the consideration of agronomic technology of individual crops. Advantages of intercropping and why it is carried out are also highlighted. This is then followed by a discussion of modern intercropping as an agronomic system emphasizing those technical aspects which influence the economic analysis.

2.1 Intercropping

For this study, intercropping is defined as the process of growing two or more crops simultaneously in the same piece of land. One of these crops, the principal crop, is coconut.

The importance of intercropping as a mean of achieving some of the national objectives have been established in the previous chapter. The writer is not aware of any studies done in Tonga to estimate existing intercropping patterns. However, there have been some studies done at the Research Division of the Ministry of Agriculture with regards to intercropping under coconuts between the age of 25-29 years old. This forms the basis for the data adopted in the final analysis.

In discussing the farming system, it is hoped to highlight the fact that intercropping is carried out with regards to most cropping activity. However, it is done in an informal manner.

2.2 The Farming System

For over a century, the tax allotment (3.34 ha) system has been practised in Tonga. Under the terms of the constitution, every tax allotment owner is directed to grow at least 200 coconut palms (Wylie, 1967, pp.620 cited in Hardaker, 1975) which will give him cash from the sale of copra. The allotment was envisaged to be sufficient to provide adequate food for the family as well as for social obligations. In addition, the farmer can also plant some cash crops. Although agriculture is principally subsistence oriented, many farmers are caught between the social demands of their kin, church and traditional leaders on the one hand and the demands of modern agriculture and their rising aspirations on the other (Ward and Proctor, 1980). Thus an important feature of the economy of Tonga is that a large subsistence sector co-exists with monetary activity.

A large proportion of most of the tax allotments is planted with coconuts. This leaves the farmer no alternative but to plant his subsistence crops and cash crops under coconuts. Thus intercropping under coconuts is an important feature of the Tongan farming system. Ward and Proctor (1980) also reported that:

> "At present, coconuts form an upper storey over much of the agricultural land but interplanting with a wide range of crops such as taro, bananas, yams is common. The coconut now represent a structural feature of the agricultural environment to which other land uses must adapt or which much be removed to make way for alternative uses."

The cropping pattern in Tonga can be described as consisting mainly of a Fallow System. The growing subsistence need for an increasing population and expanding cash production leads to a shortening of the fallow periods. Fallow system is defined as the cultivation of between 33 per cent and 66 per cent of the tax allotment annually (Ruthenburg, 1980).

Under the present farming system an area of bush fallow may be cleared either by the slash and burn technique or tractor cultivation and the land is then continuously cropped for a number of years. Duttaroy (1980) estimates that about 40 per cent of the arable land was cropped in 1979, the other 60 per cent was either left fallow or used for grazing of livestock. Hence under the current system of cropping, more than half of the arable land area is under-utilized. The use of fertilizers and effective crop rotational patterns using legumes are very restricted. Thus it is still necessary for some land to lie fallow periodically to replenish soil fertility.

The bush fallow system is an extensive production system. Much scope exists for the adoption of more intensive methods, employing new technologies of agricultural production.

The main changes in the cropping pattern in recent years have been mainly the adaptation of traditional methods rather than the introduction of new techniques. In this regard there is a need for more effective applied research and extension inputs with regards to the development of suitable systems of intercropping in Tonga.

Evidence of demand for a greater volume and variety of agricultural products for the domestic market is confirmed by the Household Consumption Survey (Duttaroy, 1980). Existing export markets can absorb a greater quantity of bananas, vanilla and to a lesser extent, root crops and vegetables.

Hardaker (1975, pp.93) concluded that:

> "Cropping patterns in Tonga give the impression of being somewhat random or erratic ..... Mixed cropping is common, both in the form of intercropping, where one crop is planted in the spaces in another crop to exploit differences in growth habit, time of maturity etc., and in the form of a more random interplanting of two or more crops on the same area."

Potentials for improvement in the production of the agricultural sector was summed up by Hardaker (1975, pp.108):

> "Nevertheless, present farming methods are still generally of low productivity. Both land and labour are used relatively extensively while capital formation within agriculture has proceeded to a very limited extent. It seems clear that, at least in principle, there is scope for the adoption of more intensive methods of agricultural production, leading to higher levels of agricultural output, income and employment."

He also pointed out that the possibility for improving the soil fertility lies in the application of technical inputs (fertilizer) and including legumes in crop rotations during the fallow period.

Thus it is evident that most cropping activities are done as intercropping under coconuts. Therefore the potential for achieving some of the national objectives lies in the further development of the intercropping system.

2.3 Reviews of Studies on Intercropping

Having examined the prevailing cropping pattern in Tonga, with reference to the potential for intercropping, we can now look at the technical basis for the economic analysis of factors affecting intercropping.

The planting of two or more crops in an area results in a complex biological system, with many complementary relationships involving such resources as nutrients, water, light and space. The long term nature of some of the crops (perennials) complicates this relationship further. In some cases the relationship between time periods may be expected to change. This may result in a change of total output. Thus in defining the input-output coefficients of an intercropping system, it is necessary to examine the agronomic characteristics of the individual crops as well as considering the time and spatial relationships of the intercrops with the principal crop.

Due to the complex relationship discussed above, there has been a divergence of opinion with regards to intercropping. Sampson (1923, pp.149-53) concluding that intercropping retards the development of the palm during the establishment phase, condemns intercropping during this period. Others including Mathur (1963, pp.38-43), Norman (1974) and Abalu (1975), in considering traditional intercropping systems, concluded that intercropping not only gives higher gross return per hectare but it also plays an important role as insurance against risk. Ruthenburg (1980) pointed out that in the humid and semi-humid tropics intercropping creates more effective and profitable land use systems. Jodha (1979) concluded that intercropping is superior over sole cropping in terms of gross return per hectare as well as per manday used during the labour scarce period of the crop season. Intercropping results in a greater and more even distribution of employment of labour.

Jodha (1979) also highlighted two important features of the traditional intercropping system. Firstly, intercropping is more important on small rain-fed farms as compared to large irrigated farms. Secondly, the traditional intercropping system is highly complex and diverse. This is because of the need to satisfy the farmers multiple objectives simultaneously.

The divergence of opinion on whether to intercrop or not has been summed up by Nair (1979, pp.46):

> "Intercropping has been popular to some extent in coconut growing countries. However, these practices of growing other crops with coconuts are often not systematic or regular; the concept of maximization of crop production per unit area and time has not been the underlying principle or motive for such practices. In most of these cases, coconut itself has been under 'low level equilibrium' management and under such conditions it is only natural that intercropping has not been intensive enough. In fact, a clear concept of the production

> potential of good cropping systems involving coconuts was itself not existing."

Willey (1979) provides a comprehensive review of intercropping literature with particular reference to annual crops, noting the prime areas of scientific investigation to be on the yield advantages and the potential control of weeds, pests, diseases and soil erosion. The complexities of possible interactions between different crops are great. Both competitive and complementary effects are possible. This depends on the specific crops considered and their relative densities. The biological basis for intercropping advantages, considering both spatial and temporal dimensions, relates primarily to the utilization of biological resources and yield stability.

In spite of the complexities discussed above, there appear to be sound scientific reasons why selected intercropping systems can increase the productivity of the agricultural sector.

In the last section of this chapter an attempt is made to look at the factors which may affect intercropping thus limiting the production of output. We can now consider some of the technical basis for modern intercropping based on research work done at the Central Plantations Crops Research Institute (CPCRI) of South India.

2.3.1 Modern Intercropping Systems

Burgess (1981) reported that:

> "The development of multi-storeyed cropping at the CPCRI arose from considerations of biological efficiency in the process whereby crops use the resources of solar energy and land mass for the production of economic output."

Theoretical calculations by Loomis and Williams (1963) indicated that under optimal conditions, the potential biological productivity of a crop community could be as high as 280.5 tonnes of dry matter per hectare per year. It is evident from Table 2.1 that under coconut monocrop, there is a wide gap between the potential and actual dry matter production.

TABLE 2.1

TOTAL ANNUAL PRODUCTIVITY OF A COCONUT PLANTATION AT DIFFERENT YIELD LEVELS

Plant Part	Total Dry Matter (Net Assimilates) Production (t/ha) at an Average Annual Yield per Palm of		
	60 nuts	100 nuts	250 nuts
Whole Nut	6.70	11.20	28.00
Spathe and Rachis	0.15	0.15	0.15
Leaves	4.60	4.60	4.60
Stem	1.50	1.50	1.50
Roots	1.25	1.25	1.25
Total	14.20	18.70	35.50

Source: Nair, 1979. (Computed from Nelliat et al, 1974. Weight of roots estimated by Khanna and Nair, 1977.)

Increasing the productivity levels of coconut plantations is limited by the fact that the efficiency of conversion of solar energy to chemical energy is much less in oil producing crops as compared to carbohydrate producing crops (Mengel, 1977; Beringer, 1977).

Soil (land mass) and solar energy are the two basic resources of practical crop production. Others such as water and nutrient represents technical inputs. The major cause for the low level total productivity in a pure coconut system is due to the under-utilization of the above resources (Nair, 1979).

Dalrymple (1975) pointed out that multiple cropping makes possible both an increase in area cultivated per year as well as an increase in total yield per unit area per unit time. This implies a better and fuller utilization of both the basic and technical resources.

With respect to perennial cropping, the crop occupies the land for more than one year. Therefore the approach at CPCRI was to examine combinations of mutually compatible crops which efficiently utilized the environmental resources. Most of the studies reviewed here with regards to intercropping are based on the work at CPCRI.

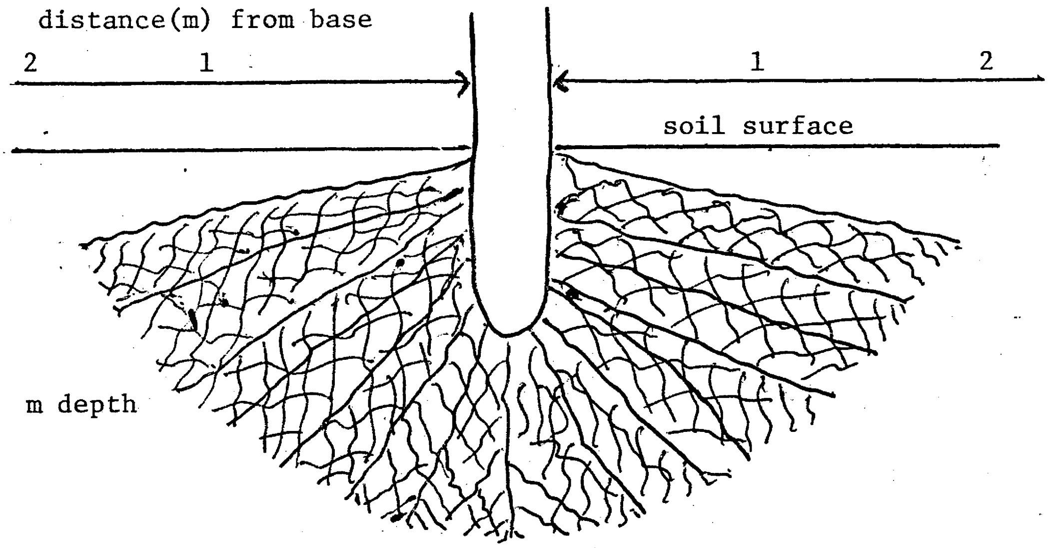
In choosing the spacing for coconut planting, an important criteria is to ensure that overlapping of leaves of adjacent palms are minimal or avoided altogether. Therefore the spacing adopted at CPCRI for the local tall variety was 7.5m x 7.5m square.

The CPCRI multistoreyed cropping formulation as discussed by Burgess (1981) and Nair (1979) is static in the sense that crop combinations considered were those planted under coconut stands which were 30-40 years old. The concept of multi-storeyed cropping is based on two issues: (a) the root system of different crops are restricted to distinct zones so as to utilize the soil volume more fully at various layers with minimum or no effect on each other; (b) the canopy orientation of different species at different levels to ensure more efficiency in the utilization of solar energy.

Recent studies at CPCRI (Kushwah et al, 1973) showed that the roots of a mature bearing palm, planted in sandy loan medium textured soil, are concentrated within a radius of 2 metres around the base. About 85 per cent of the roots are found between 30cm and 120cm depth from the surface. The top 30cm layer of soil contains virtually no roots (Figure 2.1). With coconut monocrop at normal planting density and management

FIGURE 2.1

ROOT DISTRIBUTION OF A COCONUT TREE



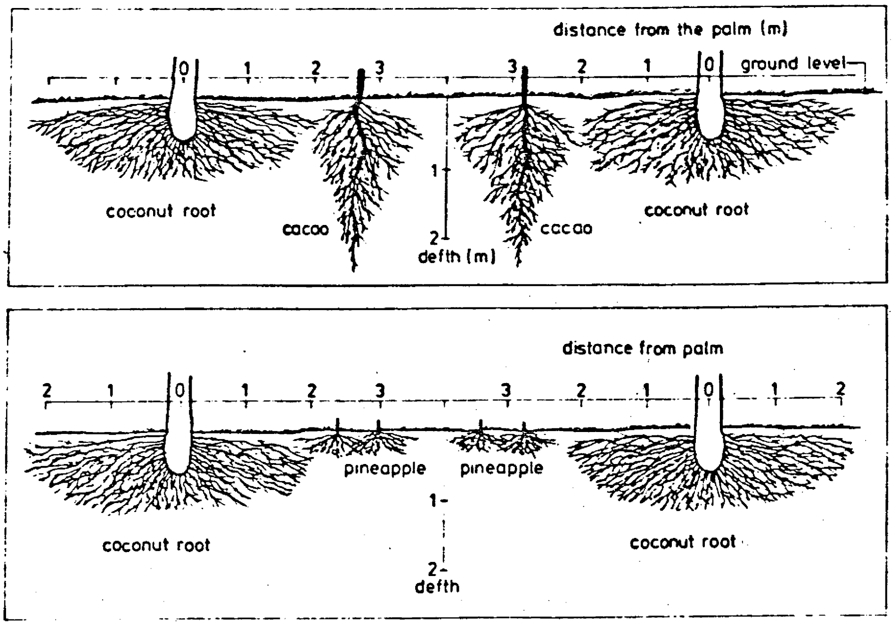
Source: Nair (1979).

conditions, only about 25 per cent of the gross land area is effectively utilized by the coconut roots. In planting the intercrops, the active root zone of the coconut has to be left free thus reducing the competition between roots for both the basic and technical resources. The net area occupied by the intercrops will vary from 65-75 per cent of the gross area depending on the method of planting (Figure 2.2(a) and (b)). Although cacao and pineapple are not included in the crops considered in this study (Chapter 4), Figure 2.2(a) and Figure 2.2(b) is presented as an example of the distribution of roots for both the intercrops and the principal crop in the different zones of the soil.

The utilization of solar energy is a dynamic factor which varies with the age of the coconut trees. The orientation of the coconut leaves together with the structure of the leaves, which resembles venetian blinds, allows part of the solar radiation to penetrate to lower levels. The

FIGURE 2.2(a)

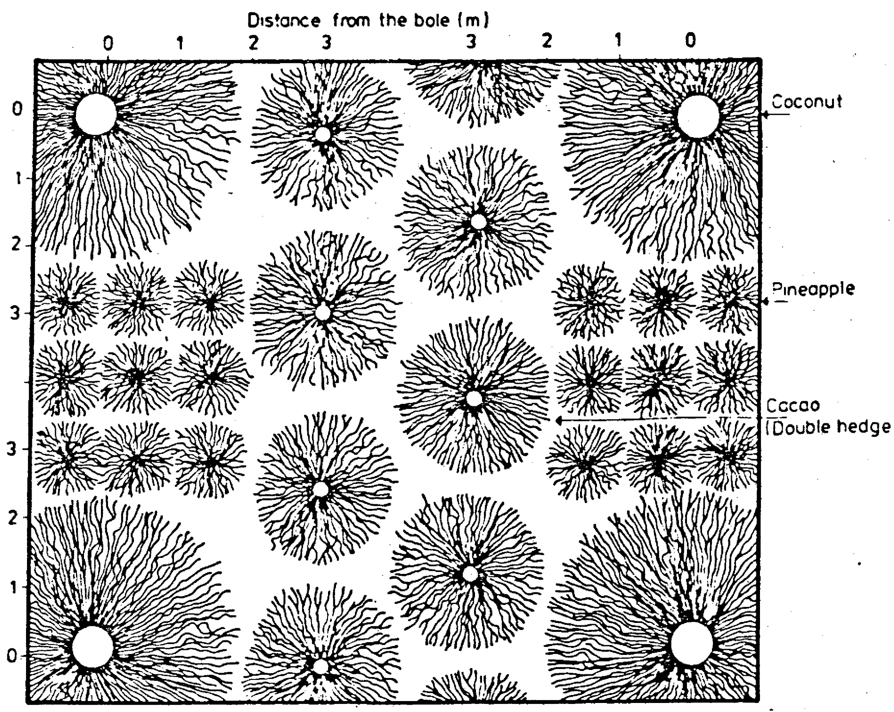
SCHEMATIC REPRESENTATION OF THE VERTICAL DISTRIBUTION OF ROOTS IN A MULTISTOREYED CROP COMBINATION



Source: Nelliat et al, 1974.

FIGURE 2.2(b)

SCHEMATIC REPRESENTATION OF THE HORIZONTAL DISTRIBUTION OF ROOTS IN A MULTISTOREYED CROP COMBINATION



Source: Nelliat et al, 1974.

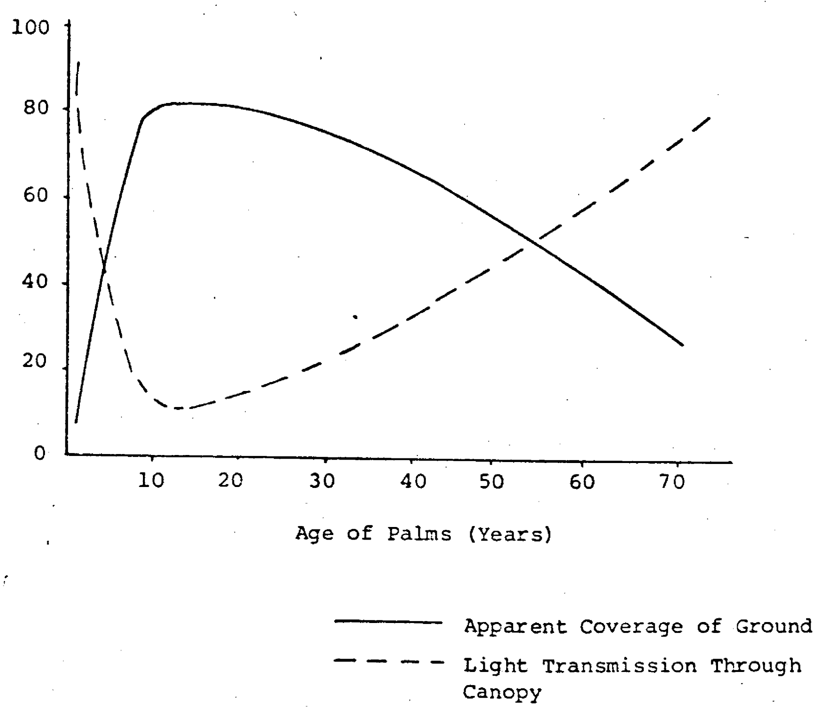
transmission of the radiation and the magnitude of the shade cast by the canopy changes with the age of the palm. This is shown diagramatically by Figure 2.3. When the palms are between 8-25 years old, the percentage of sunlight transmitted is about twenty. This percentage of light transmission increases progressively while the canopy coverage of the ground decreases inversely as the palm grows older. As the palm grows older the leaves begin to bend downwards thus interception first increases then decreases over the age of the palm.

A crop combination brings about an alteration of the local climate of the area. This is likely to modify the rates of various biological processes, regulating the productivity and growth of the crops, by influencing the environment of the crop communities. For the discussion which follows, the term ecoclimate is used instead of microclimate. Ecoclimate is defined by Nair (1979) to denote the climate which is influenced by the different crops grown. Balakrishnan et al (1976), studying a crop combination of cacao (1-3 years old), cinnamon and coconut under irrigation, found that evapo-transpiration and the variation in both the relative humidity and vapour pressure were relatively much less than the pure stand of coconut, when comparing, their ecoclimate. Nair and Balakrishnan (1977), studying the ecoclimate of coconut and cacao crop combination in comparison to that of coconut monocrop concluded that the temperature under the mixed crops is less than that for the monocrop. The variation in the relative humidity was also less in the case of the mixed crops. Thus the shading and reduced air temperature in the crop combination caused considerable reduction in the rate of evapo-transpiration in the ecoclimate of the crop combination.

Nair (1979) further reports that intensive cropping in coconut plantations enhance the microbial activity in the rhizosphere. The better

FIGURE 2.3

LIGHT INTERCEPTION AND PENETRATION
IN A COCONUT STAND OVER TIME



Source: Nelliat et al, 1974.

solubilization of phosphate, production of growth substances and the fixation of nitrogen, which results from a mixture of crops among other things, added to the causes for increased yield of coconuts. Table 2.2

TABLE 2.2

YIELD OF COCONUTS BEFORE AND AFTER PLANTING CACAO

Yield Group of Palms (Pre-experimental Yield. No.of Nuts Per Palm Per Year	Average Annual Yield of Nuts Per Palm								
	Coconut Alone			Coconut Plus Cacao in Single Hedge			Coconut Plus Cacao in Double Hedge		
	PEY	EY	Increase	PEY	EY	Increase	PEY	EY	Increase
Less than 30	19	57	38	22	74	52	15	85	69
30 - 60	50	125	75	42	141	95	53	118	68
More than 60	88	178	90	83	170	87	78	190	111
MEAN	73	120	47	67	112	45	50	109	59

Notes: PEY: Pre-experimental yield, average for two years - 1968 and 1969.

EY: Experimental yield (after planting cacao), average for three years - 1972/73 to 1974/75.

Source: Nair, 1979 (adopted from Nair, 1976).

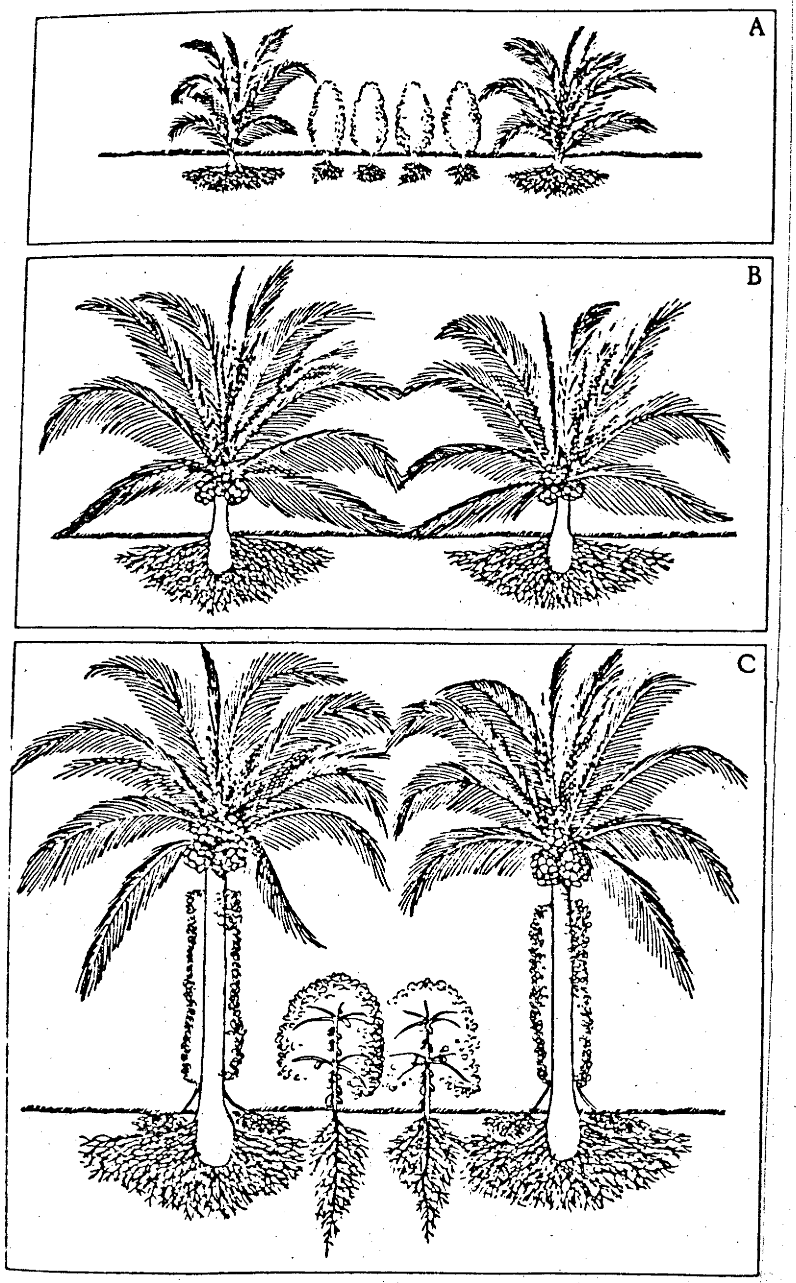
illustrates the increase in coconut yield when an intercrop (cacao) is introduced. Thus multistoreyed cropping has many advantages over sole cropping. These include efficiency of the utilization of soil nutrients, fertilizer, soil water and the beneficial effects of interaction of crop communities.

The life span of the coconut trees can be divided into three distinct phases from the point of view of intensive cropping (Figure 2.4).

FIGURE 2.4

GROWING CONDITIONS AND GROWTH HABITS

OF COCONUTS



Source: Nair (1979).

The division is based on considering an overall view of the growth of the coconut tree, interception of solar energy by its canopy and the pattern of solar utilization. The first phase is from 0-8 years old. Here there is scope for intercropping with annual or short duration crops. However, these crops must not compete with the palms for ecological requirements. The second phase is at 8-25 years of age. There is very little or no scope for intercropping during this period. The third phase covers the period from 25 years onward. There is greater potential for intensive intercropping with the increasing amount of light penetration. This analysis reveals that under normal planting density, the area under the coconuts is available for intercropping during about 75 per cent of the time. The writer is concerned about the other 25 per cent of the time where intercropping is very limited. Tonga with its limited land resource cannot afford this loss in opportunity. An alternative planting density or planting technique has to be developed to suit the requirement for Tonga. A possible alternative is relay planting where half of the coconut palms are planted in the first year and half planted about 5 years later. The writer assumes that by employing this technique, continuous intercropping will be practicable as the light constraint will be solved. However, it must be pointed out that production of half of the palms will be delayed. Apart from this, wider spacings may have to be adopted.

The importance of the root crops as intercrops was highlighted by Nair (1979, pp.48):

> "Plants in which the development of physiological sink starts early in the growth period such as root and tuber crops are likely to be less seriously affected by the shady conditions under coconuts, as compared to those whose storage organs are the grains, which have to be filled up in a relatively shorter fraction of the whole life span of the plant. Because of this and owing to their suitability for rainfed conditions, comparative ease in management, and high carbohydrate output, tubers

> are very important intercrops. On the other hand, grain legumes are potential intercrops because of their relatively short duration and high protein output. However, almost all tropical grain legumes are very sensitive to the partial shade as existing in coconut gardens."

Catedral and Lantican (1976), experimenting with soyabean under controlled artificial shade, concluded that a sunlight reduction of 40-50 per cent results in a 30 per cent decrease in yield.

In summary it can be noted that modern intercropping has considerable scope for application in Tonga. The studies under review considered 7.5m x 7.5m as the natural (optimal) spacing for local (Indian) tall coconuts. This recommended spacing is adopted so as to facilitate more fully the utilization of both the basic and technical resources. The spacing adopted in Tonga is 9m x 9m with a planting density of 123 palms per hectare. The writer is not aware of the basis for this selection.

In Tonga, water can be considered as one of the basic resources and not a technical resource as irrigation is very limited.

It should also be pointed out that because of the limited studies done in Tonga and the adoption of data from studies done elsewhere, the foregoing analysis may have some weaknesses when considered in relation to the Tongan condition.

The economic superiority of intercropping over sole coconut crops, as discussed by Nelliat and Krishna (1976), includes increased income, improved income distribution over time, increased returns on investment, risk reduction, family employment generation and cost economies in weeding. These factors are in line with the aspirations of the Fourth Five Year Development Plan for the Kingdom of Tonga.

The next chapter will discuss the alternative techniques that can be adopted for analysing the intercropping system in Tonga.

CHAPTER 3

ALTERNATIVE ANALYTICAL TECHNIQUES

There are many possible approaches to the economic analysis of intercropping under coconuts. Some approaches provide decision rules to optimise the farmer's objective function. Others do not include an optimising algorithm. This chapter will first discuss some of the difficulties encountered when time is included in the analysis. Secondly, alternative programming techniques will be discussed. The approaches which optimise the farmer's objective function will be discussed first. This will be followed by a brief discussion of Partial Budgeting. Lastly, the Multi-period Budgeting (MULBUD) program will be discussed in detail as this will be the approach adopted for the analysis.

All modelling must consist of some deviation from the real world. However, the model chosen should be able to specify a number of technical and economic inter-relationship over time, with realism.

3.1 Time

Time is incorporated into mathematical models in a variety of ways. Time enters the analysis in the Hicksian sense. Burgess (1981) compared the Hicksian to the Frisch-Samuelson sense where there is uncertainty in prices and output. Hicks writes:

> "The definition of economic dynamics --- (are) those parts (of economic theory) where every quantity must be dated.
>
> In economic statics we think of any entrepreneur employing such and such quantities of factors and producing by their aid such and such quantities of products, but we do not ask when the factors are employed and when the products come to be ready. In economic dynamics we ask such questions; and we even

> pay special attention to the way changes in those dates affect the relationship between factors and products." (Hicks, 1948, pp.115)

Hicks notes that, as in the multi-product case, we have a choice of alternative outputs because output produced in time t is different from that produced in time t+1. In evaluating the preferred production plan, the criterion for comparison is the capitalised or present value of the surplus stream. This is adopted in cases where different streams of net revenue result from alternative input strategies.

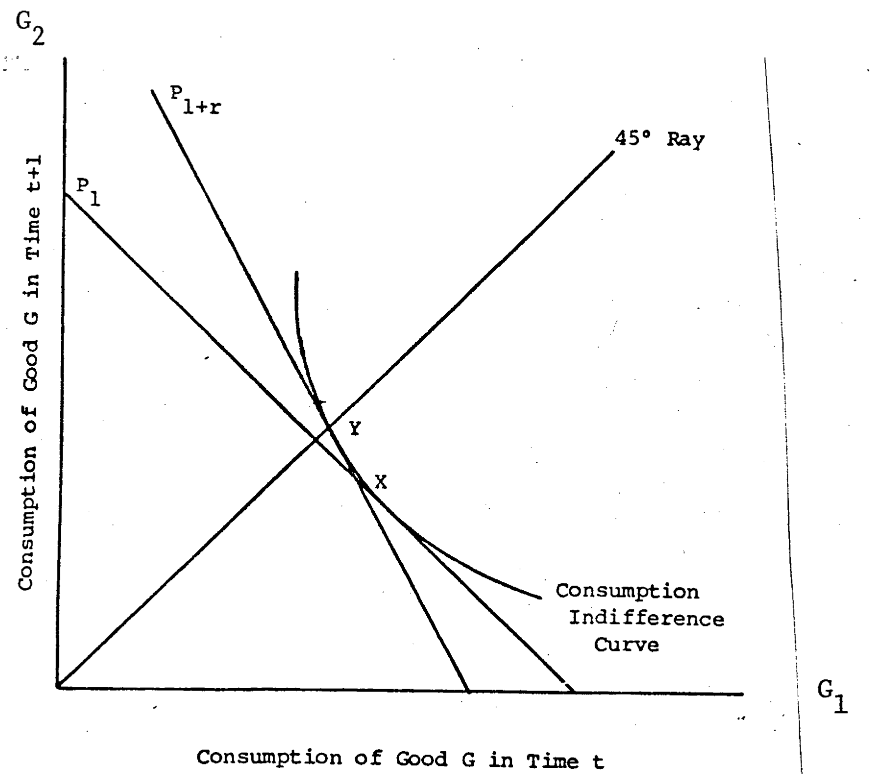
In determining the present value, the interest and interest rate expectations, price and price expectations must be known. Under perfect competition, the interest rate is the cost of borrowing one unit of money for one period. The equilibrium interest rate will equal the marginal rate of return on investment for each producer and the rate of time preference for each consumer.

Burgess (1981) states that according to Böhm-Bawek, consumer time preference exists where there is an anticipation of rising future wealth. This permits an increase in present consumption. High present marginal propensity to consume may also arise from an under-estimation of future needs. Also present goods will be preferred where they can be traded for future goods.

Time preference can be represented by consumption indifference curves. The two goods are G_2 in time t+1 on the vertical axis and G_1 in time t on the horizontal axis (Figure 3.1). Positive time preference is shown by point X, assuming that the price line P_1 represents equal prices in both periods. This means that the interest rate is equal to zero. Positive interest rates will increase the slope of the price line to P_{1+r}. The cost of present consumption will also increase. In equilibrium, the consumer is indifferent to consumption in either period, that is either

FIGURE 3.1

CONSUMER TIME PREFERENCE



Source: Burgess (1981).

consuming today or in the future. This is represented by point Y. Here the interest rate will equal the consumer's rate of time preference. The level of time preference may be influenced by factors such as short life expectancy and fatalistic philosophies. It is generally found to be inversely related to the income level.

In practice, the marginal rate of return (MRR) for on-farm investment and interest rate are not always in equilibrium. This disequilibrium was described by Upton (1966) in relation to a tree crop production model. This was used as a representative of many farm investment processes. There is an initial establishment period where inputs are utilized without producing any output. This is followed by a period where output increases while inputs are reduced to a maintenance level. The last period follows where output exceeds inputs by a constant amount. The crop is terminated at the point of replacement. If a steady state is assumed, the requirement for equilibrium will either be constant growth or zero growth. In both the above cases, a proportion of trees must be replanted each year. This proportion must be equal to the number of trees due to be replaced.

The flow of inputs and outputs are discounted to give the Sum of Net Present Value (SNPV) at a given market rate of interest. For a series of time periods, a profile of SNPVs or capitalised values can be derived. For a unique interest rate, this profile will be zero in year zero. This will be the Internal Rate of Return (IRR). At higher interest rates there will be a period for which the SNPV is negative.

In a situation of technological change, the old variety of a tree crop will have less IRR than the new variety. If finance for investment is scarce, the IRR of the new variety will equal the opportunity cost of using such finance. The capital value profile of the old variety will be negative in its initial years, when discounted at the new opportunity cost for investment finance. Thus it will no longer pay to invest in the old variety. However, existing stands, passing the period of negative capital value, would still be profitable to be maintained. As the enterprise was assumed to be in a steady state equilibrium prior to the technical change, planting with the new variety will be carried out for a number of years before equilibrium is regained. During the period of disequilibrium, it will be difficult to define a single rate of return on capital. This is due to the different rates of return that will be produced by the old and new varieties. Prices will shift thus inducing further technological change since aggregate supply functions will change due to other farmers adopting the new variety.

Given the likelihood of a continuous technological change and the time to reach equilibrium, it is not possible to assess equilibrium between the market rate of interest and the rate of return on investment opportunities. Therefore, it may be necessary to make some assumptions regarding the discount rate which represents the decision maker's time preference. This problem may be overcome by, alternative formulation of the objective function which is to be maximised, or in practice where the Development Bank sets specific rates of interest for specific programs and allocating credits through some rationing process (Burgess, 1981).

3.2 Alternative Techniques

The following section will consider the alternative programming approaches that can be adopted for the economic analysis of intercropping systems. Dynamic, Recursive and Multi-staged linear programming have been discussed by Burgess (1981). These techniques will be discussed briefly, MULBUD will be discussed in detail.

3.2.1 Dynamic Programming

The dynamic programming approach as developed by Bellman (1957) involves an optimising algorithm. This was based on the Markov requirement of dynamic programming, which requires that the optimal decision to be made at a particular stage of the process depends only on the state of the process at that stage and not on the state at any preceding stages. The path taken in reaching a state is not important, only the stage itself. The condition of the process, as described by the magnitude of the state variables, is described by the state at a particular stage. The decision applicable for any given state is defined by the policy adopted. By deriving the optimal policy for an infinite planning horizon, the dynamic programming approach provides an optimal policy for all lengths of the planning horizon. This also provides the optimal policy for all possible states at the initial stage. Burt and Allison (1963) give the following definition:

> "The stage is the interval into which the process is divided, a decision being made at each stage in the sequence of stages comprising the decision process. The state of the process, at a particular stage, describes the condition of the process, and is defined by the magnitudes of the state variables and/or qualitative characteristics. Decision making at a given stage controls the state in which the process will be found in the following stage, the control being either deterministic (with certainty) or stochastic (with a probability distribution)." (pp.121)
>
> "A policy defines the decision to be made, for a given state, at each stage for all possible combinations of states and stages." (pp.122)
>
> ".... optimal policy, i.e., one that maximizes present value of net returns over the entire planning horizon." (pp.122)

The dynamic programming approach begins with the last year of the planning horizon and works back to the current year. Burt and Allison (1963) concluded that the dynamic programming technique is a powerful computational and analytical method for handling many farm management decisions which are sequential, such as culling in breeding stock, crop rotations, fertilizer application, and farm machinery replacement. This technique is more valuable in stochastic models where there is a lack of feasible alternatives as compared to the deterministic situation.

3.2.2 Recursive Programming

Recursive programming is one of the techniques that can be used for analysing intercropping systems over time. This technique was employed by Ogunfowora and Heady (1973) to integrate short term farm enterprises with perennial tree crops using a tree crop farm settlement in Western Nigeria as an example. They defined recursive programming as:

> "a sequence of mathematical programming in which the parameters of a given problem are functionally related to the optimal variables of preceding problems of the sequence. In other words current decisions on production plans are conditioned by past decisions and performances." (pp.85)

The recursive programming model can be generalized to include planning over time. However, the generalization must be in such a way so as to allow a yearly re-evaluation of investment and production plans with regards to a new resource base, acquired skill and changes in producer preference over time, and additional information on technical and price changes. The estimates of the planning parameters are either based on expected values of these parameters in the following year or on actual performance in the previous year.

Day (1963) describes the procedure as synthesising linear programming with difference equations specifying the implicit time relationship between a variable and its value in the previous time period. The time path for the growth of a defined variable is given by the explicit solution of a difference equation.

Ogunfowora and Heady (1973) conclude that recursive models allow only a one-way relationship, that is, from one year to the next. Therefore, the recursive programming model is dynamic in both the Hicksian and Frisch-Samuelson sense when input-output coefficients and prices vary over time. Weinschenk (1971) pointed out that sequential optimising does not provide an optimal decision rule over time. It is more applicable to explaining behaviour. Thus it describes an actual growth path instead of the optimum growth path. Therefore, the value of the technique is in predicting rather than as a decision model. By considering movements in relative prices of inputs and outputs, which are less variable, the cited advantage of adjustment to changing prices is less important. Furthermore, changing technical coefficients are much less of a problem in the long run when perennial crops are considered because technological change is embodied as new varieties. Therefore, the appropriate coefficients are fixed for the life of a particular crop stand.

Ogunfowora and Heady (1973) stated that:

> "With suitable data and planning experience, conventional planning tools such as budgeting and program planning are useful when few enterprises are involved and production extends over a single year. However, these techniques are cumbersome and inadequate in complex farming situations involving many enterprises which span several years." (pp.81)

3.2.3 The Principles of Linear Programming

The linear programming model has become well established as an effective tool for decision making in situations where there are a number of variables with interdependent relationships requiring simultaneous solution in an optimising manner. In this situation the annual budgeting techniques become ineffective. Such a case can be illustrated by a multi-product firm operating with numerous resources, institutional and subjective restraints.

The linear programming model consists of an objective function to be optimised, a set of constraints, and a finite and discontinuous sets of linear equations. The objective function is a linear summation of variables representing levels of the alternative activities. These are weighted according to their contribution to the objective to be maximised. The constraints are composed of a matrix of input-output coefficients and a column vector of resource levels. There are also constraints which specify non-negative levels for each of the activities or choice variables. The solution involves a series of iterations. These bring into the basis those activities with the highest contribution coefficients within the limitations specified by the constraints. The following assumptions are a part of linear programming.

3.2.3.1 Linearity

Linearity implies constant return to scale. That is, as the output increases, there is a proportional increase in the objective. This is not as restrictive as it initially appears. Non-linearity can be approximated by fitting linear segments to the traditional production function Thus taking each segment is considered as being a different activity.

3.2.3.2 Divisibility

Divisibility assumes that all constraints and activity can be represented by infinitely divisible units. Integer programming can be used where capital investments are indivisible. This method is a variation of the linear programming technique. Indivisible items such as one tractor or labour unit inputs can be presented as tractor hours or manhours.

3.2.3.3 Additivity

Additivity assumes that each production process or activity is an independent separable process. Therefore, two activities can have either competitive or supplementary relationship without violating the requirement. However, these should be combined into one activity where complementary relationship is experienced.

3.2.3.4 Certainty

Certainty implies that technical coefficients, prices and the quantities of inputs are known. This assumption is relaxed in stochastic forms of linear programming. Sensitivity analysis can be performed within the linear programming model to determine the stability of the solution with respect to different prices and resource levels.

3.2.4 Multi-stage Linear Programming

In the literature, the terms poly-period and dynamic programming are also used in lieu of the above. However, there may be confusion between this dynamic programming and that developed by Bellman (1957).

3.2.4.1 Time in Linear Programming

Linear programming becomes multi-stage when time is introduced in the analysis. The time concept is Hicksian. Inputs, outputs and technical coefficients are dated according to the time in which they are used or produced. The introduction of time represents an expansion of the simplex model. Different activities are required to produce the same output in different time periods.

Other variations in the model include the need to account for inter-relationships of constraints and activities through time. As the objective function represents a stream of net revenue over time, it is necessary to consider time preference. This can be done by using an appropriate discount rate to obtain present values by discounting the future income streams.

Labour and capital inputs will also change over time when considering the growth of the firm. Transfer activities are used to move the surplus capital to the next period.

Finally, it is important to take into account the utilization of income when dealing with the family farm. Income is required to meet fixed and variable farm costs, loan repayments, income tax repayments, family living costs, capital expenditure and personal savings. Burgess (1981) describes the inclusion of time in linear programming more fully.

3.2.5 Partial Budgeting

Within the framework of Farm System Research (FSR) (Norman, 1978), the analysis of intercropping systems has ranged from very large linear programming models for the whole farm (Barlow et al, 1979) to whole farm Program Budgeting and on to simple partial budgets at the activity or enterprise level. Each of these techniques has its particular use. Farm System Research is the term used to describe efforts to develop readily applicable cropping innovations.

Budget techniques are important because they demonstrate the economic benefits of changes in cropping pattern or the type of crops grown. While on the other hand, linear programming models have a fundamental research orientation.

Partial Budgeting, by definition, is concerned with the changes that occur in a farming system caused by the introduction of a new, or an alternative technology. The method adopted for Partial Budgeting is a variation of the method described and used by others such as Stanton (1973) and Anderson (1976). Partial Budgeting analysis concentrates on the most limiting resources and usually in the form of discrete steps in investment rather than in marginal analysis. This does not work well for any presentation of economic assessment of the perennial cropping system. Etherington (1980) states that:

> "It (Partial Budgeting) abstracts from such important areas of economic theory as the multi-decision maker, multi-product firms producing for multiple (distinct) markets over a period of many years. Such an analysis cannot hope to capture all the complexities of investment analysis, portfolio selection, risk and uncertainty, the economies of scope and interdependencies, not to mention the biological life cycle of the family, the new household economics and marketing structures." (pp.15-6)

To arrive at the crucial number of variables which are representative of the technological relationships to be assessed within the budget, many variables must be assumed to be constant. In order to understand and appreciate the reaction of the proposed technology to possible changes in external factors and what changes in assumptions will be implied, a sensitivity analysis should be undertaken with regards to some of the key variables. For a new technology to be adopted, the judgement is based on the 'with' and 'without' situation.

There are two decision levels which are required when considering intercropping. Firstly, whether intercropping has any advantage over sole cropping. Secondly, what are the advantages of the crop combination. Most annual budgets take note of the timing of the farm operations. However, they can usually abstract from the cost of time. Partial Budgeting, for perennial crops, cannot afford this. Explicit account must be taken of the passage of time if serious errors in advice are to be avoided (Barlow, 1978, Etherington, 1977). The introduction of time into the analysis, using partial budgets, for perennial crops, create some complications. There is the cost of time itself for which there are well defined discounting techniques to account for. Also, a given technology may give different economic results depending on the time of introduction. This may be due to both the growth pattern of perennial crops, which may alter the environment into which the technology is introduced, and the cost of time itself. Partial Budgeting may be easy to use with annual crops but problems in calculation will arise when perennial crops are considered. These problems may arise due to the shift in the time for the introduction of the intercrop and the undertaking of a reasonable sensitivity analysis.

Attempts, which have been made to analyse the economics of alternative perennial intercropping systems include: linear programming (Burgess, 1981), annual budgets (Nik Faud et al, 1980) and relatively forward discounting exercises. The annual budgets ignore the time dimension by assuming a 'steady state'. The time path of the growth to maturity of different crops is not considered. Most analyses which are based on 'net present value' undertake very little sensitivity analysis. Etherington (1981) concluded that:

> "None of these methods provide the farm - systems economist and the non-economist with an economically valid yet readily understandable equivalent to the partial budget used to evaluate annuals crops."

This leads to the requirement for the development of a general multi-period partial budgeting system for the economic analysis of intercropping systems for perennial crops. This is MULBUD, an approach which also handles annual crops effectively.

3.2.6 MULBUD

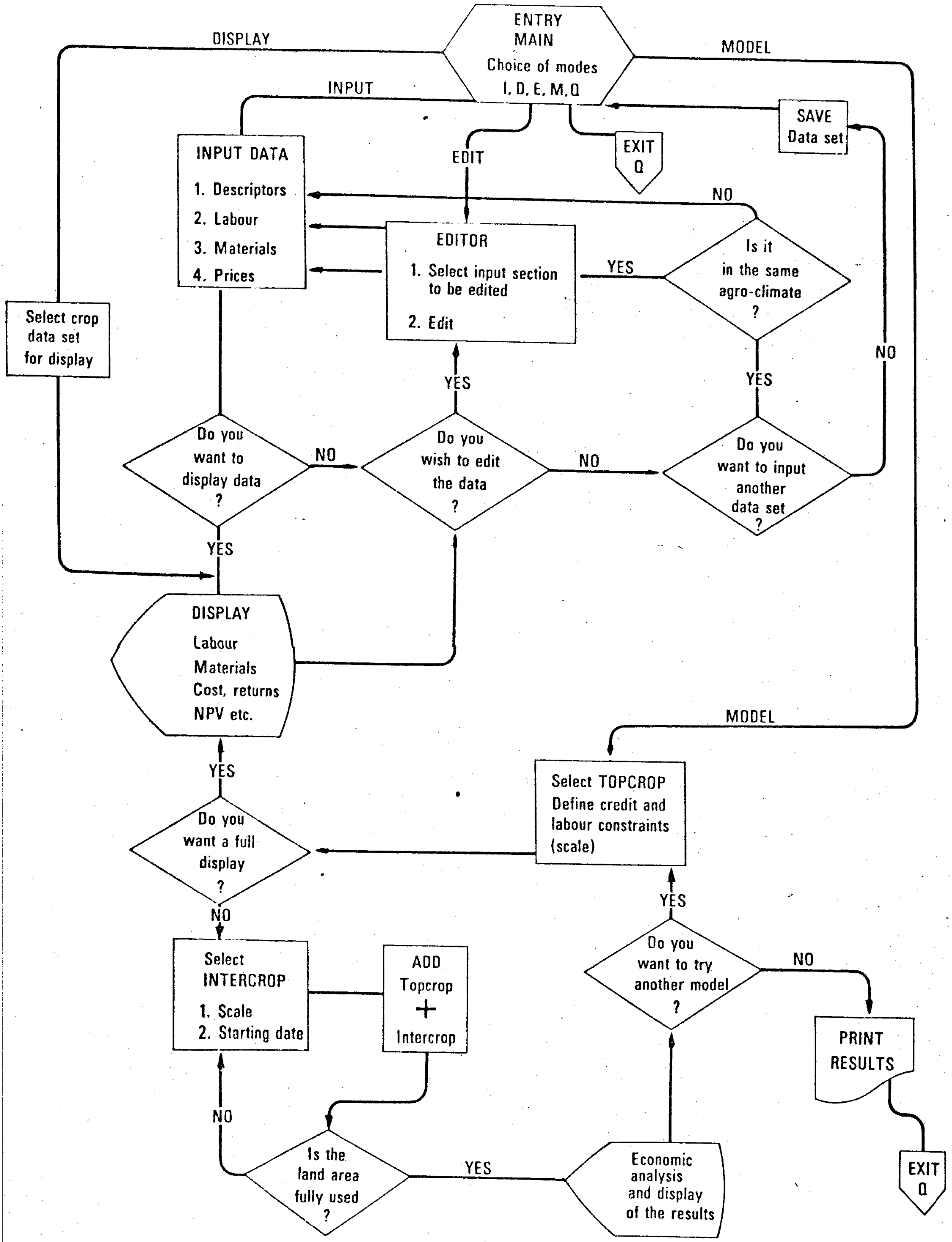
MULBUD is a recently developed technique for the economic assessment of intercropping systems (mainly for perennial crops). It is a general, interactive, multiperiod budgeting program. A detailed description of the program is given in Etherington (1980, 1981). A major reason for designing MULBUD as an interactive program was to ensure that consistent and comparable data sets are created. In many respects, this program is closely related to the Monte Carlo farm plan programming technique. However, the selection of farm plans here is purposive rather than random. The MULBUD program does not include an optimising algorithm.

3.2.6.1 The MULBUD Program

The program is written in ANSI Standard Fortran occupying about 24K of memory. It is in modular form so that the major components have 'stand alone' capabilities. The structure of the program is presented in Appendix E, Figure E.1. Figure 3.2 represents a schematic flow chart which will help to understand the logic of the program. The user is given

FIGURE 3.2

SCHEMATIC FLOW CHART OF 'MULBUD'



Source: Etherington (1981).

a number of options when he enters the MAIN. He can choose to INPUT data, DISPLAY or EDIT a data set already in memory, create an intercropping model or leave the MAIN. There is also a documentary HELP module which is designed to assist first time users. This is not shown in the flow chart.

Once the data input mode is entered (through logging in and typing RUN MULBUD), a series of headings (prompts) will appear. These will require data responses. The first set of prompts, 'Descriptors', requires the crop name as well as assumptions regarding the agro-climatic zone in which the crop is grown. In the modelling component, some of these descriptors are used to prevent the user from operating with incompatible data sets. The required descriptors are presented in Appendix E, Table E.1. While most of the descriptors are names or scalars, some are vectors over time. For any data set, the user is required to state the number of years and seasons per year for the analysis. Thus data will be presented on a seasonal basis. The data collection format is presented in Appendix E, Table E.2(a) and Table E.2(b). For example, with the Tongan data used in the analysis, for vanilla (<u>Vanilla fragrans</u>), three seasons are chosen and the analysis is taken over 15 years. Banana (<u>Musa spp</u>.), on the other hand, adopted 4 seasons with a time period of 7 years. Crops with different seasons and agro-climatic factors cannot be combined in MODELLING. Selection of seasons may vary between countries depending on the crops considered, availability and nature of the data, and the climatic conditions. However, the seasons must be of the same length.

Following the 'Descriptors' the user is required to give labour inputs in vector terms. This is defined by the years and seasons. All the inputs and outputs must be defined on a per unit area basis depending on the unit adopted. The results can be produced on a per hectare or per acre basis regardless of the unit of the original data. The labour data requirement is presented in Appendix E, Table E.3. The labour unit is defined as labour days. There is no allowance for separate labour categories by sex or age. Thus any allowance necessary has to be calculated by hand before entry in the program. Separate labour categories may be important in determining the equivalent mandays of available family labour. Most of the labour inputs are made prior to the production of outputs. However, harvesting, processing and selling labour requirements are a function of the yield. The user is required to define the linear function in each according to the formula a+bX where a and b are constants and X refers to the yield (Appendix E, Table E.3).

Next the data entry requires prices and costs. The product price is entered as a vector. This also allows for seasonal fluctuations and price trends. This is the same for the wage rates. Hired labour and family labour are separately defined. Material inputs, whose prices are required in scalar forms, are defined by name. Two pesticides and two fertilizers are allowed for in the program. The material inputs, output and price data requirements are presented in Appendix E, Table E.4. For the output, two variables are required. These are, the terminal value for the end of the planning horizon for the crop and a yield vector specifying the year and season. Only one product is allowed for each crop. For example, the yield of coconuts can be either copra, nuts, desiccated coconuts or coconut oil and not a mixture of two or more. However, additional products can be included as another crop in modelling (Appendix E, Table E.4). When the data entry sequence is completed, the user has a well defined technological matrix and price coefficients.

When the data input is completed the user is returned to the MAIN. The user will then specify the next requirement. For the DISPLAY the user can display the data fully (computation completed) or he can select different tableaux of labour data, material inputs and costs, or a summary display which gives total labour, total costs, gross revenues and net revenues per season. An economic assessment in terms of the SNPV and SNPV per labour day is presented at the end of the summary display. These results can be presented for up to 5 different discount rates. All the discount rates are defined on an annual basis. They are converted within the program to equivalent seasonal rates. The next table presents a sensitivity analysis on increases and decreases in gross revenue and material costs. The user can choose the percentage limits.

The data set can now be edited. New assumptions will generate new results. The main purpose of the top half of the flow chart (Figure 3.2) is to store data (technological matrix) for the modelling of intercrops.

The MODEL mode of MULBUD is also interactive. The prompts will firstly require the user to specify his top level shade crop (TOPCROP). Next, the assumed constraints under which the model will be operating are required to be entered. The constraints specified in the model are family labour supply, capital (credit) and light. These constraints are more informative rather than binding in nature. The capital constraint is defined in terms of a lump sum credit advance. This is to be paid off as an annuity, at a specified interest rate, over a specified time period. The displayed results of a model shows clearly when a constraint is exceeded. If the user wishes to remain within the constraint boundaries he can modify his set of assumptions. The family labour supply is defined on a seasonal basis. All labour requirements above the family labour available is assumed to be hired labour. The hired wage rate and family wage rate can be defined separately, allowing for difference in opportunity costs and seasonal variations. Another constraint is the land area available for cropping. This is the only binding constraint. The amount of land used, in terms of gross area, is initially determined by the Land Use Factor (LUF). This gives the area occupied by a mature crop under the spacing specified for the crop.

Once the top crop has been identified and the constraints specified, the intercrops are called one at a time to facilitate the modelling process. The user is made aware of the land available for intercropping after each crop, and must scale the crops down in order not to exceed the available land. The user will specify the year in which the intercrop is to be entered. A given intercropping system may be approached by a number of different time paths. Each path may give a different economic result. Considerable flexibility is allowed in model building by shifting the input/output vectors and by scaling the LUF. The output of MULBUD for modelling contains calculations and summations of physical and monetary values, graphical displays and a sensitivity analysis table. Definitions of the structural equations of the model and output values are presented in Appendix E, Table E.5.

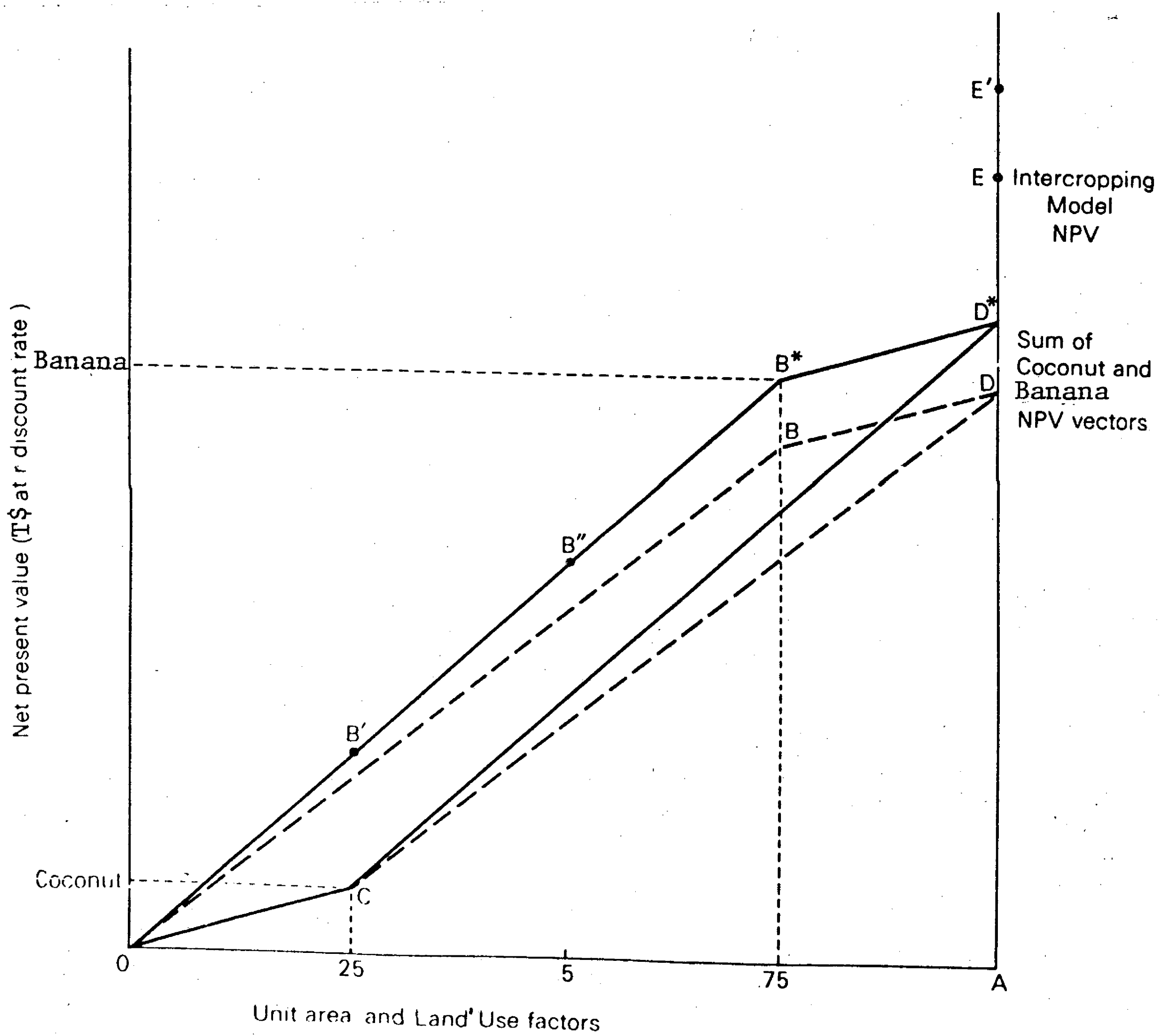
The interaction effects caused by the association of different crops is crucial to the concept of intercropping. It is impossible to give mathematical expressions to every possible interactive effect. However, MULBUD allows the user to define three logical interactive effects. These are labour inputs for weeding, fertilizer application and pest control. Other interaction effects such as yields are left to be decided by the user. Therefore, the judgement of the user is an essential part of MULBUD.

MULBUD provides a tool for the rapid reply to the question: "What are the economic implications of growing different crops with the assumption that certain features occur?"

The final economic assessment of the advantage of intercropping should be in some form of comparison with another cropping pattern such as monocropping. Therefore, the logical alternative in this case is the linear combination of individual crops. Figure 3.3 shows one possible

FIGURE 3.3

NET BENEFITS FROM INTERCROPPING



Source: Etherington (1981).

way of representing the above comparison. The figure gives the sum of the vectors of the net present value (NPV) of two crops, banana and coconut. DA represents the unit area in which the intercropping takes place. OC is the vector representing the gross area occupied by the coconut trees (25 per cent). Extrapolation shows the NPV value. Vector OB^* shows the gross area (75 per cent) taken up by the intercrop (banana). OD^* represents one specific convex combination of the crops. It is the sum of the two vectors OA, and OB^*. However, since sole cropping requires additional land as compared to intercropping, we must make an allowance for the opportunity cost of the land. Assuming that the opportunity cost is reflected by planting the additional area with coconut, the two sole crop alternative will have a NPV at D. AE represents the NPV of the intercropping model. The net advantage of intercropping is represented by the ratio AE/AD. This ratio could be termed the Net Benefit Ratio (NBR). The different time paths for the introduction of banana in the model could result in different NPVs. Another alternative is represented by AE'. A similar diagram could be drawn with NPV per labour day replacing NPV. Thus NBR may be changed to Labour Benefit Ratio (LBR).

3.2.6.2 Analytical Requirements

The analytical requirements of MULBUD can be categorised into the following:

(a) Valid Economic and Scientific Analysis

The prime motivation of MULBUD is to undertake valid economic analyses noting the constraints with regards to labour, capital, land and time. The biological constraints of rainfall, soil, terrain and insolation are also included as these factors may affect production as well as the type of crops grown. The suggested objective to be maximized includes the SNPV and SNPV per labour day.

(b) Clarity of Assumptions

The environment in which crops are grown can affect the growth pattern of the crops. Therefore, assumptions for the analysis must be clear.

(c) Interactive Effects

Because of the impossibility of deriving a general interaction equation, biological interaction effects have to be introduced by the user. However, some economic interactions are likely to be of a general nature, for example, labour requirement for weeding. These are likely to be reduced in an intercropping system as compared to monocrops. These are included in the analysis.

(d) Sensitivity Analysis

The rapid arithmetic potential of the computer is used to build in sensitivity analysis of discount rates, costs and revenue.

The MULBUD can be adopted to devise different models. These models may not only satisfy the multiple objectives of the farmers but will also consider the locational constraint. The locational constraint will also affect the types of crops to be grown. The MULBUD program can be used to develop alternative crop models for the farmers to choose from. This is in line with the objective of the study.

The next chapter will discuss the cash flows of the different crops that will be considered in the intercropping models. The computation of the cash flows is done with the use of MULBUD.

CHAPTER 4

THE CROPS AND THEIR CASH FLOWS

This chapter examines individual crops that will be considered in the intercropping models in terms of their Sum of Net Present Values (SNPVs), net revenue and SNPV per labour day. The cash flows are determined by considering the adopted input-output relationships. Studies done in Tonga, together with experimental data were used for this analysis. Data from studies done elsewhere were also used. The experimental data were a result of intercropping trials carried out under 25-29 year old coconuts by the Research Division of the Ministry of Agriculture, Forests and Fisheries (M.A.F.F.). Other studies in Tonga reported a range of both inputs and yields for certain crops. In cases where intercropping data were not directly available, the writer estimates the data adopted from other general studies mentioned above.

The studies reviewed includes discussion on: (a) crop yields; (b) prices of outputs and costs of inputs; (c) crop preference and their importance for domestic consumption, social obligations as well as export potentials; (d) the constraints in production; and (e) the likelihood of an expanded export and domestic market. This enables the writer to assess the future of individual crops. The export markets for the crops, except Kava (Piper methysticum) and copra are mainly New Zealand and Australia.

The analysis is done on a per hectare basis. It is assumed that the costs and yields adopted for the analysis are those for crops planted under coconuts (Cocos nucifera). Most of the studies done in Tonga were on a per acre basis. The data were converted to a per hectare basis assuming constant returns to scale.

4.1 Coconuts (Cocos nucifera)

Although coconut products consistently account for the Kingdom's highest export earnings (Table 1.11) it is regarded by the Tongan farmers as a secondary crop, the primary crops being the intercrops.

4.1.1 The Coconut Yield Stream

There is no complete data available for the yield streams of coconut over time for Tonga. The data available is limited to raw data from the Research Division of the M.A.F.F. The coconut yields for 25-29 year old palms, planted at a spacing of 9m x 9m square, were recorded for the years 1976-1980. The coconut palms involved were the local tall variety. The result of trials carried out by the Research Division of the M.A.F.F. with regards to intercropping and fertilizer application is summarised in Table 4.1. The trials were done in 4 replicates. When considering the coconut yield means under different intercropping systems, there seems to be no significant difference. For individual years, there is no consistent trend in the coconut yield stream with regards to different intercrops. With regards to the fertilizer treatment, the result is inconclusive. Some years reported an increase (1976, 1979, 1980) while others do not (1977, 1978).

Dean (1981) estimates that about 5,000 nuts will produce one tonne of copra. The domestic consumption, excluding industrial use, accounts for about 26 per cent of the coconut produced (Appendix A, Table A.1). From the coconut acreage and the export production data, Dean estimated that 2.5 tonnes of copra is produced from 3.34 hectares (tax allotment). The tax allotment may consist of coconuts of varying ages and land without coconuts.

TABLE 4.1

YIELD COMPARISON FOR 25-29 YEAR OLD COCONUTS

(A) Comparison Under Different Intercropping Systems

Crop	Yield (nuts per tree per year)					Mean
	1976	1977	1978	1979	1980	
Kava Tonga	52.89	66.86	70.52	60.74	50.06	60.21
Vegetables	55.61	70.64	75.41	55.04	46.88	60.72
Root Crops	53.66	66.91	73.67	58.40	46.75	59.89

(B) Comparison of Fertilizer Treatment

No Fertilizer	51.04	71.42	76.28	56.00	44.50	59.85
Only Coconut Fertilized	59.36	64.11	72.62	56.84	51.67	60.92
Only Intercrop Fertilized	51.77	66.56	71.54	56.03	45.58	58.30
Both Intercrop and Coconut Fertilized	54.05	70.47	72.36	60.70	49.90	61.50

Note: The November yield data are missing for the years 1978 and 1980. No adjustment was done as this will not change the relationship within the data set.

Source: Raw Data from the Research Division of M.A.F.F.

Burgess (1981) presented an adopted yield data for Western Samoa for coconuts from 5-65 years old. These are comparative yields for different spacings. Due to the data limitation for Tonga, the above data was adopted for the analysis.

Burgess (1981) reviewed some studies before adopting his data. Frémond and de Lamothe (1972, pp.317) presents comparative yield streams in kilograms of copra per hectare per year for a hybrid variety (Malayan Yellow Dwarf cross West African Tall) and the West African Tall variety. The observations were limited to 4-9 years old for the hybrid and 6-13 years old for the tall variety.

Rector et al (1972, pp.256) adopted a yield stream for palms from 36-60 years old, expressed in monetary terms. They assumed an average yield of 1,490 kilograms per hectare per year. The projected yield decline was due to natural age effect and was assumed to be about 150 kilograms per hectare over a successive five year cycle.

Frémond and Ouvrier (1972) reported yield streams for African Tall coconuts from commencement of bearing at 8 years old to 16 years old in relation to fertilizer experiments. Von Uexküll (1972) did likewise but the yield considered ranges from 8-13 years old. Burgess (1981, pp.35) reported:

> "the analysis establishes statistical significance between the control and the fertilizer treatments independently at each age without considering that the observations are also observations on a particular yield stream over time. Without deriving the underlying yield stream it is not possible to establish overall statistical significance or even stochastic dominance for the treatments."

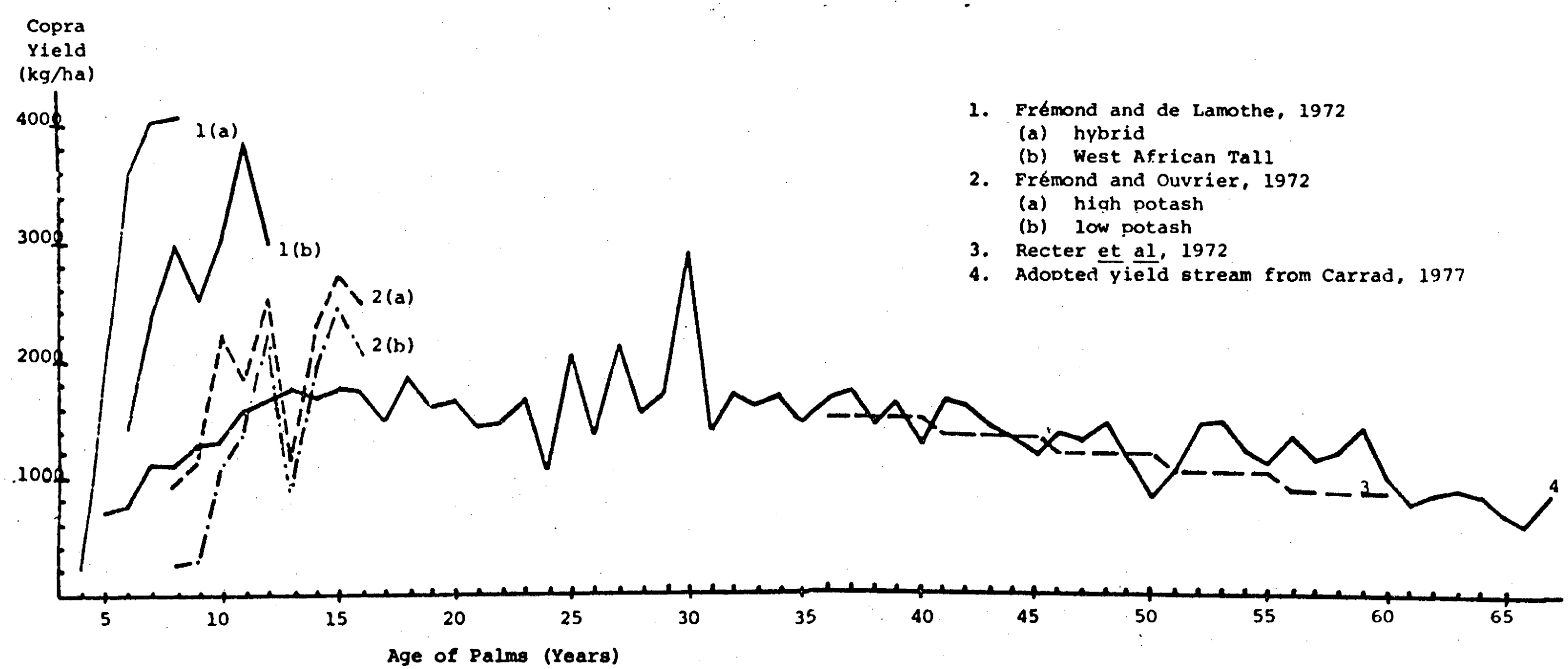
De Silva's data (1976) was also reviewed by Burgess (1981). This data appears to represent output per plot thus yield cannot be pinpointed reliably.

The data from the above studies are presented for comparison in Figure 4.1.

Valuable data for the coconut yield streams are available from the study of the Lever Plantations Pacific Pty Ltd (LPPPL) in the Solomon Islands. The study was carried out by Carrad (1977). Previously, Green and Foala (1961) studied the yield streams for two estates planted in

FIGURE 4.1

COMPARATIVE COPRA YIELD CURVES



Source: Burgess (1981), pp.37.

1907-1908. This data covers a period of 30 years. Data was also analysed for three other estates planted in 1907, 1917, and 1923, respectively. The analysis covers a period of 17 years. The curves, that they present, shows a production peak at around 14-16 years and again at 30 years. There was no statistical information presented with regards to the fitting of the curves. The differences between the five estates includes location as well as different planting densities. These differences should have a marked effect on the output.

Carrad (1977) in studying the LPPPL estates adopted the methodology of Etherington (1973) to overcome some of the problems faced by Green and Foala (1961). Where plantings were spread over a number of seasons, the output and yield were predicted on the basis of the cohort structure of the coconut stand.

For the LPPPL estates, the yearly output data and the age distribution of the trees were known. The planting periods vary from 5-12 years between the estates and records of first production ranges from 4-6 years after planting. The output production records vary from 13-31 years. Finally, two planting densities of 139 and 170 palms per hectare were used.

The differences between estates includes soil type, rainfall pattern, exposure to sunlight and wind and topography. For the analysis, a dummy variable was included to account for the estate differences.

Estate output was recorded as dry tonnes of copra thus assuming a constant conversion and collection technologies over the period. Although there were experiments and improvements regarding copra driers the same conversion ratio (55 per cent) was maintained. However, the expansion of cattle grazing was expected to improve harvesting conditions and reduce nut loss but the extent of its influence probably does not detract from the essential age-output relationship.

Price was included in the analysis as a yearly figure, as differences from the trend, and also as a one year lagged difference but they made an insignificant contribution to explaining changes in output or yield.

Although the results show a high Durbin-Watson statistic (D.W. 0.86) indicating the presence of auto-correlation in the residuals, it has a high explanatory power ($R^2 = 0.87$). The coefficients for 'estate effects' and for ages were also significant. Adjusting the 'estate effect' by the constant (0.92 kilogram per tree) and the age coefficient by the constant (0.53 kilogram per tree) gave the yield per tree at each age (Table 4.2).

The age feature of the model refers to biological features also, which may reverse itself due to climatic or other influences. The yield increases up to the 13th year after which the palms annual yield fluctuation becomes greater and increasingly biennial. Reversal of the biennial trend occurs at the 22nd and 29th year (Figure 4.2).

This analysis removes the density factor, which biases the per hectare measurement, by using yields per palm. Although the Green and Foala (1961) results were possibly biased by combining two different densities in their analysis, the possibility of the 15 year peak that they suggested cannot be absolutely ruled out by the Carrad (1977) yield curve.

Further data were available for the LPPPL for 1961-1974. Carrad (1977) analysed this data using the least squares regression technique to try to explain the variation in output caused by a number of factors but without success. However, it was still possible to derive

TABLE 4.2

COCONUT AGE COEFFICIENTS FOR YIELD PER PALM (Kg)
ADJUSTED FOR AVERAGE ESTATE EFFECT

Variable	Yield	Yield Adjusted*
Age 5	1.74	2.66
Age 6	2.22	3.14
Age 7	4.69	5.61
Age 8	4.60	5.52
Age 9	5.87	6.79
Age 10	6.09	7.01
Age 11	8.11	9.03
Age 12	8.86	9.78
Age 13	9.38	10.30
Age 14	8.89	9.81
Age 15	9.40	10.32
Age 16	9.27	10.19
Age 17	7.48	8.40
Age 18	10.07	10.99
Age 19	8.33	9.25
Age 20	8.73	9.65
Age 21	7.02	7.94
Age 22	7.42	8.34
Age 23	8.75	9.67
Age 24	4.32	5.24
Age 25	11.48	12.40
Age 26	6.49	7.41
Age 27	12.00	12.92
Age 28	7.82	8.74
Age 29	9.04	9.96
Age 30	17.76	18.68
Age 31	6.81	7.73
Age 32	9.04	9.96
Age 33	8.38	9.30
Age 34	3.03	3.95
Age 35	20.69	21.61

Notes: * Average 'estate effect' was 0.92 kg copra.

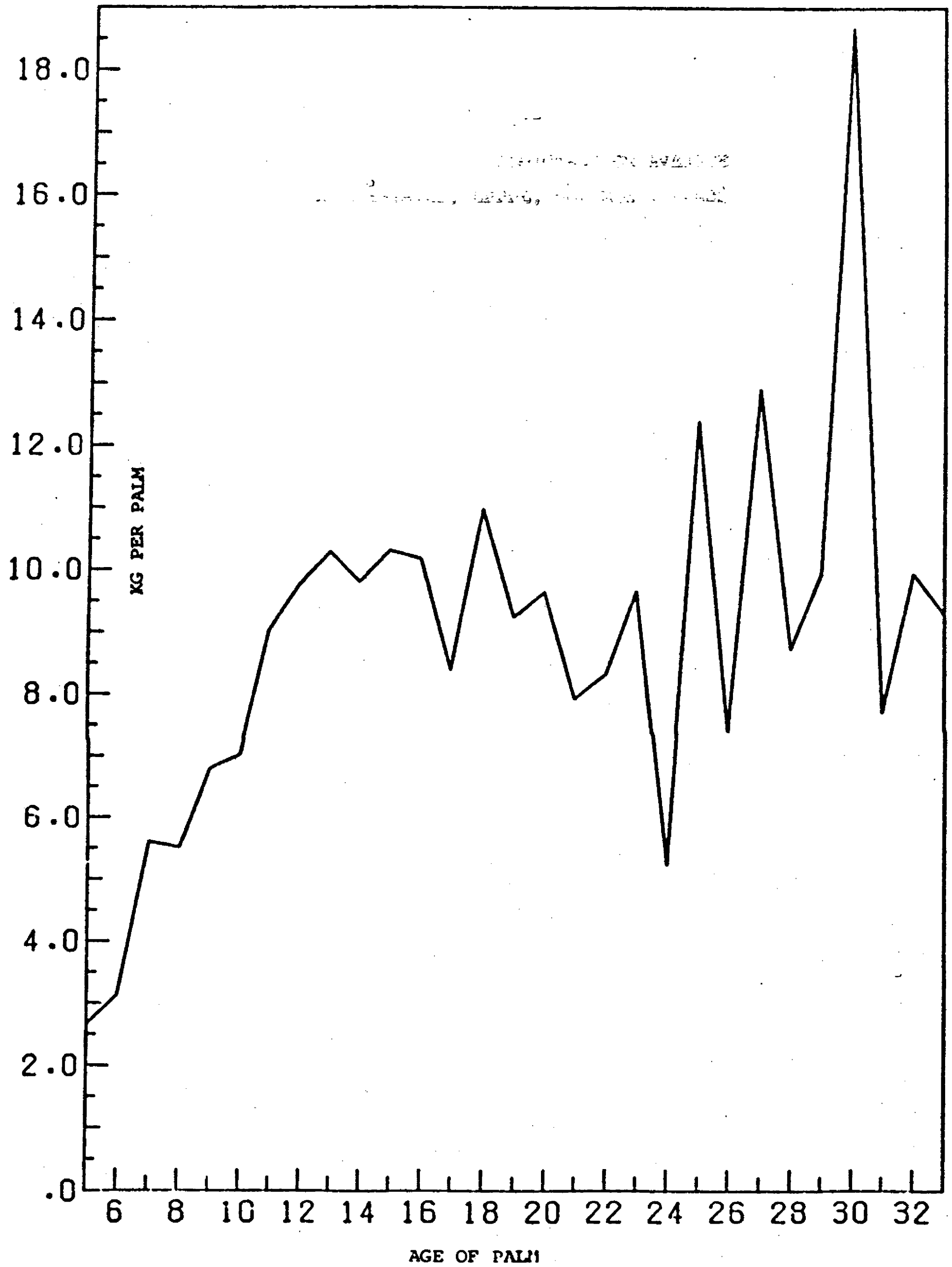
* Average 'age effect' was 0.53 kg copra.

Source: Carrad, 1977.

information about yield per tree and to group them in an age sequence (Table 4.3). The main conclusion was to confirm that the most significant determinants of estate output are palm age, number and location.

FIGURE 4.2

COCONUT YIELD CURVE PREDICTED FOR AVERAGE
OF SEVEN ESTATES, LPPPL, SOLOMON ISLANDS



Source: Carrad, 1977.

TABLE 4.3

YIELD PER PALM FOR SOME LPPPL ESTATES,
1961-1974 (Kg)

Average Age Palm	Lingatu	Somata	Sifola	West Bay	Banika	Pepesala	Adopted Yield Coefficient
35	7.7						7.7
36	7.8						7.8
37	7.8						7.8
38	8.1						8.1
39	7.0						7.0
40	6.1						6.4
41	6.6	8.0					6.6
42	7.2	7.3					7.2
43	6.8	7.5					6.8
44	8.1	7.1					8.1
45	8.7	6.8					8.7
46	6.9	5.1					6.9
47	4.5	6.1					6.1
48	5.0	5.9					5.9
49		10.0	8.4				10.0
50		6.8	6.1	4.9	4.0		6.8
51		7.8	7.8	4.6	3.9		7.8
52		5.4	10.7	6.4	4.9	5.9	5.4
53		3.6	10.8	6.9	4.6	6.5	3.6
54		6.2	8.9	7.2	6.7	5.7	6.2
55			8.1	6.6	5.6	6.2	6.2
56			7.8	7.3	5.0	5.6	5.6
57			8.4	7.4	5.2	4.6	4.6
58			8.9	8.1	6.1	5.4	5.4
59			10.4	8.6	6.5	5.1	5.1
60			7.3	10.1	6.1	5.4	5.4
61			5.5	9.6	4.9	5.7	5.7
62			8.3	7.6	4.3	5.5	5.5
63				7.8	6.3	4.7	4.7
64						4.5	4.5
65						4.7	4.7

Source: Carrad, 1977.

The yield adopted for the analysis of coconut production in Tonga is based on Burgess (1981, pp.47-8). Although this yield is based on estate production with inputs of fertilizer and pesticides, it is shown in Table 4.1 that the corresponding yield without fertilizer in Tonga is slightly higher. The yield stream for Tonga, considering only one planting density is presented in Table 4.4.

TABLE 4.4

COCONUT YIELD STREAMS

(DENSITY - 123 PALMS PER HECTARE)

Year	Yield (kg/tree)	Yield (kg/ha)	Yield (nuts/tree)	Yield (nuts/ha)
5	2.7	332	14	1660
6	3.1	381	16	1905
7	5.6	689	28	3445
8	5.5	677	27	3385
9	6.8	836	34	4180
10	7.0	861	35	4305
11	9.0	1107	45	5535
12	9.8	1205	49	6025
13	10.3	1267	52	6335
14	9.8	1205	49	6025
15	10.3	1267	52	6335
16	10.2	1255	51	6275
17	8.4	1033	42	5165
18	11.0	1353	55	6765
19	9.3	1144	47	5720
20	9.7	1193	48	5965
21	7.9	972	40	4860
22	8.3	1021	41	5105
23	9.7	1193	48	5965
24	5.2	640	26	3200
25	12.4	1525	62	7625
26	7.4	910	37	4550
27	12.9	1587	64	7935
28	8.7	1070	43	5350
29	10.0	1230	50	6150
30	18.7	2300	93	11500
31	7.7	947	38	4735
32	10.0	1230	50	6150
33	9.3	1144	47	5720
34	4.0	492	20	2460
35	7.7	947	38	4735
36	7.8	959	39	4795
37	7.8	959	39	4795
38	8.1	996	40	4980
39	7.0	861	35	4305
40	6.4	787	32	3935
41	6.6	812	33	4060
42	7.2	886	36	4430
43	6.8	836	34	4180
44	8.1	996	40	4980
45	8.7	1070	43	5350
46	6.9	849	35	4245
47	6.1	750	30	3750
48	5.9	726	29	3630
49	10.0	1230	50	6150
50	6.8	836	34	4180

TABLE 4.4 (Cont'd)

Year	Yield (kg/tree)	Yield (kg/ha)	Yield (nuts/tree)	Yield (nuts/ha)
51	7.8	959	39	4795
52	5.4	664	27	3320
53	3.6	443	18	2215
54	6.2	763	31	3815
55	6.2	763	31	3815
56	5.6	689	28	3445
57	4.6	566	23	2830
58	5.4	664	27	3320
59	5.1	627	25	3135
60	5.4	664	27	3320
61	5.7	701	28	3505
62	5.5	677	27	3385
63	4.7	578	24	2890
64	4.5	554	22	2770
65	4.7	578	24	2890

Notes (1) The figures on nut yield are rounded to the nearest whole number.

(2) It is assumed that 5,000 nuts produce 1 tonne (1,000 kg) of copra.

(3) The kilogram yields represent copra output.

Source: Adopted from Burgess (1981).

The estimated yield from the productivity survey (Appendix A, Table A.3) is much lower than the yield adopted. However, because of the general nature of the survey, this analysis adopts the Burgess (1981) data with modification on coconut yield per palm and per hectare.

4.1.2 Coconut Product Prices

Tonga is exporting coconut products in a variety of forms. Copra is the main export while there is also a sizeable amount of desiccated coconut and coconut oil being exported. A limited quantity of whole coconuts are also exported. Apart from this, both green and mature coconuts are sold on the domestic market.

Rector et al (1972, pp.259) presented copra price projections for 1971-1995 in Malaysian dollars. This price projection was based on the main assumption that the price for copra is likely to decrease due to a greater and wider use of palm oil and further increase in the acreage of oil palm production. The projected price assumption for 1971-1975 was based on the average price for the last 17 years. It was assumed that from then on, the copra price will decrease by \$16.18 per tonne f.o.b. every successive 5 years. Burgess (1981), considering the 1969-1971 FAO Price Index for lauric oils, assumes that on the average, 70 per cent of the f.o.b. price was a relevant producer price for Western Samoa. Tonga is a price taker in the export market. The producer price, which is set by the sole marketing agent, Commodities Board, fluctuates according to the movement of the f.o.b. price.

Dean (1981) estimated the producer price at T\$250.00 per tonne of copra. At 5,000 nuts per tonne, this is equivalent to 5 seniti per nut. The M.A.F.F. purchased seednuts at 5 seniti per nut. The Commodities Board also purchased nuts for the desiccated coconut factory at an average rate of 5 seniti per nut. The writer assumes that Dean's (1981) price per tonne of copra was based on previous copra prices.

A relevant price for the analysis should include all the different prices of coconuts. Such price will be $P = l_1P_C+l_2P_D+l_3P_O+l_4P_G+l_5P_M+l_6P_E$ where:

P = price per tonne, i.e., 5,000 nuts.

P_C= price of copra per tonne.

P_D= price per tonne of desiccated coconuts x $^{5000}/_{6000}$.

P_O= price of coconut oil from one tonne of copra.

P_G= price of 5,000 green nuts at domestic market.

P_M= price of 5,000 mature nuts sold at domestic market.

P_E= price of exported mature nuts per 5,000.

l_1-l_6 = percentage of total production used in each category.

It was estimated in the Third Five Year Development Plan that about 6,000 nuts produces one tonne of desiccated coconut. Because information for the above formula is not available, a price of T$5.00 per 100 nuts is adopted.

4.1.3 Cost in Smallholder Production

In Tonga, the usual procedure for the new planting or replanting of coconuts is to plant them in areas where a crop has already been planted. This is to ensure the maintenance of the coconut palms in terms of weeding. In the case where coconuts are to be planted in virgin land, it is assumed that the slash and burn technique is adopted which is the general practice. Generally the existing palms are not removed when new planting or replanting is done. In cases where the old palms are removed, it is utilized as coconut timber. For the analysis it is assumed that the return from the coconut timber balanced out the costs of removal.

Burgess (1981) referred to Hung (1976) who discussed the development of the Metarrhizium fungus which is a parasite on the rhinoceros beetle (Oryctes rhinoceros) larvae. This fungus, when applied to coconut stumps, would permit them to rot without becoming breeding sites for the beetle. This technique is carried out in Tonga by the M.A.F.F. For the analysis this is regarded as costless to the smallholder producer. However, as Burgess (1981) pointed out this will reduce the effective intercropping area by about 4 per cent.

Clearing in preparation for tractor work requires 4 mandays/ha. This involves the removal of shrubs. Tractor cultivation which consists of slashing, is the main component for the removal of ground cover. This is estimated at 4 hours costing T$11.00 per hour.

Lining and holing requires 6 mandays. This includes the marking, measurement and digging of coconut holes using the maximum hole size (0.3m cube) as recommended by Liyanage (1963). Other studies reviewed by Burgess (1981) includes Oisher (1970) who reported a 30 manday per hectare for Papua New Guinea; Carrad (1977) reported A$44.00 per hectare for the LPPPL estates.

Planting requirement is estimated at 2 mandays at a density of 123 palms per hectare. Burgess (1981) adopted a planting requirement of 60 seedlings per manday, Oisher (1970) referred to 18 mandays per hectare while Carrad (1977) established a cost of A$7.00 per hectare.

As there has been very limited work done with regards to fertilizer application in Tonga and the inconclusive result from the Research Division (Table 4.1) plus the fact that almost all the coconut plantings in Tonga are done without fertilizer application, zero fertilizer requirement is adopted in the analysis.

Seedlings, although raised by the Ministry of Agriculture Forests and Fisheries and distributed free of charge, are given a nominal cost of 5 seniti each or T$5.00 per hundred.

The analysis adopted manual weeding although it can also be done by tractor work (slashing) or by weedicides. It is assumed that the weeding requirement decreases up to the 4th year then remains constant at 5 mandays per quarter thereafter. For the last 5 years weeding is assumed to be 4 mandays per season.

Dean (1981) estimated that for 2.1 tonnes of copra (10,500 nuts), harvesting or collection requires 5.25 mandays, processing requires 43.4 mandays. Thus harvesting and processing are estimated at about 23 mandays per tonne of copra. Harvesting and processing requirements change with the yield. For the analysis it is assumed that half a manday is required to collect the first 100 nuts. Further requirement will be decided by the formula in Appendix F, Table F.1. The processing of the first 100 nuts is estimated to require 3 mandays. Further processing requirements will be determined by the formula in Appendix F, Table F.1. Selling is estimated at about half a manday per quarter. A transport cost per quarter of T$5.00 is also allowed for in the analysis although a horse and cart may be available free of charge. Other studies on harvesting and processing includes Lockwood (1971) who estimated harvesting and processing for four Western Samoan villages at 22 mandays per tonne. The Papua New Guinea Department of Agriculture, Stock and Fisheries (1973) estimated a mode of 20-30 mandays per tonne of copra.

4.1.4 Coconut Fixed Costs

The fixed costs for coconuts are presented in Appendix B, Table B.1. These are limited to basic tools which are essential for the production process.

4.1.5 Coconut Cash Flow

The coconut cash flow and labour input requirement is presented in Table 4.5. As 'MULBUD' currently works with 48 seasons, the analysis was done accordingly. The coconut life was divided into 12 year periods, each year containing 4 seasons. The final period consists of only 5 years, each containing 4 seasons. A terminal value is given to each period. This is the market value of the coconut stand at the end of the period. For the following period, a re-purchased value is adopted. This is the same as the terminal value for the previous period. The terminal value was calculated using the formulae in Appendix E, Table E.4. The terminal value

TABLE 4.5

ANNUAL COCONUT CASH FLOW AND LABOUR INPUTS

Year	Total Labour (Days)	Total Costs (T$)	Net Revenue (T$)
1	48	262.00	-262.00
2	31	153.20	-153.20
3	28	132.00	-132.00
4	24	116.00	-116.00
5	40	181.72	-99.72
6	41	184.72	-88.72
7	45	201.16	-29.16
8	45	200.72	-30.72
9	47	209.36	0.64
10	48	210.64	5.36
11	51	223.60	52.40
12	52	229.24	72.76
13	53	232.24	83.76
14	52	229.24	72.76
15	53	232.24	83.76
16	53	231.84	82.16
17	50	219.72	38.28
18	54	237.00	101.00
19	51	225.76	60.24
20	52	228.36	69.64
21	49	216.28	25.72
22	50	219.28	36.72
23	52	228.36	69.64
24	45	198.56	-38.56
25	57	246.52	135.48
26	48	213.24	14.76
27	57	249.52	146.48
28	50	221.88	46.12
29	56	230.52	77.48
30	67	288.40	287.60
31	49	214.96	21.04
32	57	230.52	77.48
33	51	225.76	60.24
34	42	190.36	-68.36
35	49	214.96	21.04
36	49	215.84	24.16
37	49	215.84	24.16
38	49	218.00	32.00
39	48	210.64	5.36
40	47	206.76	-8.76
41	47	207.64	-5.64
42	48	211.96	10.04
43	47	209.36	0.64
44	49	218.00	32.00
45	50	221.88	46.12
46	47	209.80	2.20
47	46	204.60	-16.60
48	46	203.32	21.32

TABLE 4.5 (Cont'd)

Year	Total Labour (Days)	Total Costs (T$)	Net Revenue (T$)
49	57	230.52	77.48
50	47	209.36	0.64
51	49	215.84	24.16
52	45	199.84	-33.84
53	42	187.76	-77.76
54	46	205.04	-15.04
55	46	205.04	-15.04
56	45	201.16	-29.16
57	44	194.68	-52.68
58	45	199.84	-33.84
59	44	197.68	-41.68
60	45	199.84	-33.84
61	41	186.00	-10.00
62	41	184.72	-14.72
63	40	179.12	-35.12
64	39	167.80	-39.80
65	40	179.12	-35.12

for the last period refers to the timber value of the coconut stand. Table 4.6 presents a summary of the returns at 6 per cent discount rate for separate periods.

Basing on the adopted prices, costs and yield the net revenue remains negative up to the 8th year. It becomes positive in the 9th year and increases up to the 13th year. From the 14th to the 51st year, it fluctuates with some years recording negative values. The net revenue becomes negative for the rest of the coconut life (Table 4.5). In practice, the trend in fluctuation may be amplified by changing prices and climatic factors. In Tonga, the price per tonne for copra may be a major determinant with regards to the amount of copra produced. Therefore, coconut production may be high while copra production is low.

TABLE 4.6

SUMMARY OF RETURNS AND AVERAGE

LABOUR USE

Crop and Age	SNPV	Amortized Value per Year	SNPV Per Labour Day	Average Annual Labour Use
Young Cocaut (0-12 year)	-150.05	-17.90	-0.30	42
Mature Coonut 1 (13-24 yeas)	-144.45	-17.23	-0.23	51
Mature Coonut 2 (25-36 yeas)	29.29	3.49	0.05	52
Mature Coonut 3 (37-48 yeas)	-389.94	-46.51	-0.68	48
Old Coconu 1 (49-60 yeas)	-460.25	-54.90	-0.83	46
Old Coconu 2 (61-65 yeas)	-84.70	-20.11	-0.42	40

\t 6 per cent discount rate, the SNPV for the different 12 year periods rages from -T$460.25 to T$29.29 while the amortized value ranges from -T$5490 to T$3.49. The SNPV per labour day ranges from -T$0.83 to T$0.05 (Tale 4.6). This is much lower than the adopted hired wage rate of T$4.00. From these results we can conclude that coconut sole cropping is not ver profitable. Therefore, there is a need for supplementing income thrugh intercropping of coconut land.

4.2 Cassa'a - Manihot esculenta

lassava, which can be planted and harvested at any time of the year has been apart of the traditional intercropping system for a long time. This is a shade tolerant crop and is included in the intercropping model as a consumption crop and for domestic sale. Cassava is treated by farmers as a security crop against food shortage because of its high yield and low input cost. Hardaker (1975) stated that cassava is the most widely grown root crop in Tonga.

4.2.1 Cassava Yields

Cassava occupies the land for a period of 9-12 months depending on the rate of harvesting. The yields vary mainly with planting density. For the analysis, a traditional double spacing of 0.3m x 0.9m x 0.9m with a yield of 15 tonnes per hectare is adopted. The cassava planting materials are the setts.

4.2.2 Cassava Prices

There is a marked fluctuation in cassava prices in the domestic market. The price is influenced by the quantity of other root crops which are on sale. It must be noted that cassava is regarded as an inferior crop as compared to other root crops. The price adopted for the analysis is 10 seniti per kilogram (Eisinger, 1981, pp.33).

4.2.3 Cost of Cassava Production

A summary of costs and returns is presented in Table 4.7. As cassava is introduced in the model both as a cash crop and a subsistence crop, the planting material input is not costed. This is freely available either from a previous crop or from other farmers. Generally, planting materials are abundant. However, T$10.00 is allowed for in the analysis to cover transportation cost.

One manday is required to prepare the land for tractor cultivation. This constitutes the major cost in land preparation. The tractor cultivation which may include slashing, ploughing, disc harrowing or ridging requires 8 hours per hectare at T$11.00 per hour.

TABLE 4.7

ANNUAL CASSAVA CASH FLOW AND LABOUR INPUTS

I	Yield		15241 Kg/Ha
	Price		10 seniti/Kg
	Gross Revenue		T$1,524.10
II	Costs (T$)		
	(A) Production Cost		
	Tractor cultivation	8hr @ 11.00	88.00
	Planting materials		10.00
	Labour is costed at 4.00 per manday		
	(i) Clearing	1 manday	4.00
	(ii) Lining and holing	15 mandays	60.00
	(iii) Planting	7 mandays	28.00
	(iv) Weeding	42 mandays	168.00
	Subtotal		358.00
	(B) Harvesting Costs		
	(i) Labour	30 mandays	120.00
	(C) Marketing Costs		
	(i) Processing	7 mandays	28.00
	(ii) Selling	6 mandays	24.00
	(iii) Materials and transport		25.00
	Subtotal		77.00
	Total Cost		T$555.00
	Net Revenue		T$969.10
	Total labour requirement		110 mandays
	At 6 per cent discount rate the:		
	(i) SNPV		892.98
	(ii) SNPV per labour day		8.12
	(iii) Amortized value per year		946.56

Lining, holing and planting require 22 mandays (Eisinger, 1982, pp.34). Planting includes the collection of the planting materials.

Weeding accounts for one of the major labour requirements in cassava production. This is done manually with a bush hoe during the first 7 months requiring 42 mandays per crop.

An allocation of 30 mandays for harvesting is allowed for. This includes lifting the tubers and separating them from the stem (Appendix F, Table F.1).

Processing takes 10 mandays. This includes removing of dirt from the tubers and packing in baskets woven from coconut leaves (Appendix F, Table F.1).

Selling, which includes transportation to the market, requires 7 mandays (Appendix F, Table F.1).

Generally farmers do not apply fertilizers or chemicals so these are not budgeted for in the analysis.

Marketing cost includes the cost of transportation and space rental at the domestic market. Transportation costs vary with the distance from the market. For the analysis, a cost of T$25.00 is adopted, assuming that 10,000 kg are marketed.

4.2.4 Cassava Fixed Costs

The fixed costs for cassava are limited to basic tools and is given in Appendix B, Table B.1.

4.2.5 Cassava Cash Flow

The costs and return information are summarised in Table 4.7. At a 6 per cent discount rate, the SNPV is T$892.98 and the return to labour is very high with a SNPV per labour day of T$8.12. This is much higher than the adopted hired wage rate of T$4.00 per day. The total annual labour requirement is 110 labour days. The production cost is T$358.00

of which labour cost accounts for 73 per cent. The amortized value per year if T$946.56.

4.3 Yams - Dioscorea alata, D. esculenta and other D. sp.

Yam is the most preferred crop in the Tongan staple diet. Farmers prefer to grow their own crop rather than rely on purchases. The planting of yam has been traditionally done in areas where bush or forest has just been cleared, but nowadays such areas are scarce so most crops are grown under coconuts. Yam, which is not as shade tolerant as swamp taro and Xanthosoma, is planted as the first crop, after fallow, in the traditional cropping pattern. Yam is a highly valued crop for both consumption and for fulfilling social obligations.

4.3.1 Yam Yields

Yam is harvested after 9-12 months from planting. Yields reported by both Eisinger (1981, pp.38) and Weber et al (1980, pp.44), ranges from 12-24 tonnes per hectare. The yield is highly dependent on the quality of the planting materials, type of trellising used, planting densities and the management level especially during crop growth. The Research Division of the Ministry of Agriculture Forests and Fisheries (Annual Report 1980, pp.82) reported average yields of 10-14 tonnes per hectare. For the analysis, a spacing of 1.8m x 3m with a yield of 10 tonnes per hectare is adopted.

4.3.2 Yam Prices

While the prices in the export market fluctuates markedly, the prices in the domestic market remain high. Yam exports have increased from 36 tonnes in 1975 to 232 tonnes in 1979 thus showing an increasing demand trend. Weber et al (1980, pp.44) reported a price range of 20-45 seniti per kilogram for export yams from 1975-1979. They estimated the domestic price at 41 seniti per kilogram.

As most of the yield is consumed locally, a price of 40 seniti per kilogram is adopted.

4.3.3 Cost of Yam Production (refer Table 4.8)

Yam is introduced in the model mainly as a subsistence crop although its importance as a cash crop is increasing in both the domestic and export market. Because of this, an attempt is made to evaluate all inputs and outputs.

Yam planting requires about 1,320 kg/ha of planting materials. These are the edible tubers. Therefore, the planting materials are not costless to the farmers. Hence a cost of 40 seniti per kilogram is adopted. This amounts to T$528.00 per hectare.

Two mandays are required for clearing the land in preparation for tractor cultivation which requires 8 hours per hectare at T$11.00 per hour.

Lining, holing and planting accounts for one of the major labour requirements. Holes have to be dug to about 0.60m deep. This is assumed to be done by hand with a digging spade and requiring 40 mandays. Planting requires 5 mandays and includes the preparation of the planting materials.

Weeding is done by hand using a bush hoe mainly because yam is a creeper and there is limited possibility of using weedicides. It is assumed that weeding is carried out during the first 7 months and requires 66 mandays.

It is the general practice to use trellising to provide footholds for the yam vines. Seven mandays is allowed for this. This process involves cutting of tree branches and placing them on top of the yam mounds.

Harvesting involves the lifting of the tubers and transporting them to the farmers home. This always requires more labour than holing

TABLE 4.8

ANNUAL YAM CASH FLOW AND LABOUR INPUTS

I	Yield		10161 Kg/Ha
	Price		40 seniti/Kg
	Gross Revenue		T$4,064.40
II	Costs (T$)		
	(A) Production Cost		
	Tractor cultivation	8hr @ 11.00	88.00
	Planting materials	1320Kg @ 0.40/Kg	528.00
	Pesticides		39.40
	Labour is costed at 4.00 per manday		
	(i) Clearing	2 mandays	8.00
	(ii) Lining and holing	40 mandays	160.00
	(iii) Planting	5 mandays	20.00
	(iv) Weeding	66 mandays	264.00
	(v) Pest control	7 mandays	28.00
	(vi) Trellising	7 mandays	28.00
	Subtotal		1163.40
	(B) Harvesting Costs		
	(i) Labour	62 mandays	248.00
	(C) Marketing Costs		
	(i) Processing	10 mandays	40.00
	(ii) Selling	10 mandays	40.00
	(iii) Others		600.00
	Subtotal		680.00
	Total Cost		T$2091.40
	Net Revenue		T$1973.00
	Total labour requirement		201 mandays
	At 6 per cent discount rate the:		
	(i) SNPV		T$1846.88
	(ii) SNPV per labour day		T$9.19
	(iii) Amortized value per year		T$1957.69

since care is taken so that the tubers are not damaged. It is estimated that harvesting requires 62 mandays (Appendix F, Table F.1).

Ten mandays are allowed for processing which involves the removal of dirt and roots from the tubers. It also includes transportation to the packing centre where yams are packed into 25 kilogram cases supplied by the marketing authority or they are transported to the domestic market for local sale (Appendix F, Table F.1).

Selling, which involves the actual transaction in the domestic market, is estimated to require 10 mandays as most of the yield are sold locally as compared to export (Appendix F, Table F.1).

For the marketing costs, it is assumed that 5,100 kilograms are exported. Costs include 204 cases at T$1.75 per case, Commodities Board levies on export earnings of 7.5 per cent, domestic market space rentals and the cost of transportation. These are estimated to total T$600.00.

Generally fertilizer is not applied in yam production and this is assumed in the analysis. For the model, 4 kilograms of the pesticide Carbaryl 80WP are required for pest control and 7 mandays for the application.

4.3.4 Yam Fixed Costs

The yam fixed costs are limited to basic tools and are given in Appendix B, Table B.1.

4.3.5 Yam Cash Flow

The costs and returns information for one hectare of yam production are summarised in Table 4.8. Although the labour requirement in mandays is higher than for the other root crops, the return to labour is still very high. At 6 per cent discount rate, the SNPV is T$1,846.88 and the SNPV per labour day is T$9.19. The total labour requirement is 201 mandays. Yam has a high production cost of T$1,163.40. This is due mainly to the high cost of planting materials and the high labour requirements. The cost of planting materials is T$528.00 (45%), other materials is T$127.40 (11%) and labour is T$508.00 (44%).

4.4 Swamp Taro - Colocasia esculenta

Swamp taro, which is a shade tolerant crop, has been grown as an intercrop under coconuts for a long time in South Pacific agriculture. It can be planted at any time of the year. In the traditional cropping system, it is usually planted after the yam crop is harvested.

4.4.1 Swamp Taro Yields

Swamp taro can be repeatedly planted over a period of three to four years without any significant decline in yield. A traditional spacing of 0.9m x 0.9m is adopted with an average yield of 4,931 kilograms per hectare. One crop occupies the land for a period of 9-12 months. The yield varies according to the planting densities and the level of management practices. The yield adopted for the analysis is based on raw data for intercropping under 25 year old coconuts from the Research Division of the Ministry of Agriculture.

4.4.2 Swamp Taro Prices

The price fluctuation is very significant in the export market which includes New Zealand, Australia, American Samoa and Nauru, in that order of importance. The increasing demand for exports is reflected in the increase of export quantities from 316 tonnes in 1975 to 1,347 tonnes in 1979 (Weber et al, 1980, pp.50). This trend is likely to continue as more Pacific islanders migrate either to New Zealand or Australia. Weber et al (1980, pp.41) reported an export price range of 30-57 seniti per kilogram between 1975 and 1979. The price adopted is 30 seniti per kilogram.

4.4.3 Cost of Swamp Taro Production (Table 4.9)

As swamp taro is introduced in the model solely as a cash crop, an attempt is made to evaluate all inputs and outputs. Planting materials may be available free from a previous crop or from other farmers. However, for the analysis a price of T$1.00 for 100 planting materials is adopted.

Labour requirement for land preparation is restricted to one manday while tractor cultivation requires 8 hours at T$11.00 per hour.

Lining, holing and planting requires 12 mandays. This includes the collection and preparation of planting materials.

Weeding accounts for the major labour cost. Weber (1980, pp.42) and Eisinger (1981, pp.55) reported a labour requirement of 42 mandays. For the analysis it is assumed that weeding is done during the first 7 months requiring 46 mandays.

Harvesting includes lifting of the tubers, cutting off the tops and transporting to the farmer's home. This is estimated to take 15 mandays (Appendix F, Table F.1).

Processing includes the removal of soil and roots from the tubers, transportation to the packing centre and packing in 25 kilogram cases supplied by the marketing authority. This requires 10 mandays (Appendix F, Table F.1).

Selling accounts for 2 mandays. This includes transporting the export rejects to the domestic market and the time taken to sell the produce (Appendix F, Table F.1).

It is assumed that 95 per cent (4,925 kg) of the yield is available for export while 5 per cent is sold in the domestic market.

Marketing costs include 197 cases at T$1.75 per case, Commodities Board levies on export earnings of 7.5 per cent, transportation cost, and

TABLE 4.9

ANNUAL SWAMP TARO CASH FLOW AND LABOUR INPUTS

I	Yield		4931 Kg/Ha
	Price		30 seniti/Kg
	Gross Revenue		T$1479.30
II	Costs (T$)		
	(A) Production Cost		
	Tractor cultivation	8hrs @ 11.00	88.00
	Planting materials		100.00
	Pesticides	4kg Carbaryl 80WP @ 7.75	31.00
	Labour is costed at 4.00 per manday		
	(i) Clearing	1 manday	4.00
	(ii) Lining and holing	7 mandays	28.00
	(iii) Planting	5 mandays	20.00
	(iv) Weeding	46 mandays	184.00
	(v) Pest control	7 mandays	28.00
	Subtotal		483.00
	(B) Harvesting Costs		
	(i) Labour	15 mandays	60.00
	(C) Marketing Costs		
	(i) Processing	10 mandays	40.00
	(ii) Selling	2 mandays	8.00
	(iii) Others		500.00
	Subtotal		548.00
	Total Cost		T$1091.00
	Net Revenue		T$388.30
	Total labour requirement		94 mandays
	At 6 per cent discount rate the:		
	(i) SNPV		346.56
	(ii) SNPV per labour day		3.71
	(iii) Amortized value per year		367.35

space rental at the domestic market. A total of T$500.00 for marketing costs is adopted.

Generally swamp taro is grown without fertilizer application and this is the assumption in the model. However, the Research Division of the Ministry of Agriculture, Forests and Fisheries has been carrying out trials with fertilizer application. The results, so far, have been inconclusive.

For pesticides, 4kg of Carbaryl 80WP is required. Two sprayings per month is recommended with a total application requirement of 7 mandays.

4.4.4 Swamp Taro Fixed Costs

The swamp taro fixed costs are limited to basic tools and is presented in Appendix B, Table B.1.

4.4.5 Swamp Taro Cash Flow

The cost and return information for swamp taro is presented in Table 4.9. At a discount rate of 6 per cent, the SNPV is T$346.56 and the SNPV per labour day is T$3.71 which is slightly lower than the adopted wage rate of T$4.00 per manday.

The production cost is T$483.00 of which about 55 per cent (T$264.00) is labour cost, 21 per cent (T$100.00) is planting material cost, and 24 per cent (T$109.00) is machinery and pesticide cost.

A total of about 93.4 mandays is required per crop. About 50 per cent of this is the weeding requirement.

4.5 Taro Futuna - Xanthosoma

Xanthosoma is the most shade tolerant of the root crops and can be grown at any time of the year. This crop is not valued as highly as the swamp taro in the subsistence diet but it can be left unharvested for up to three years. Because of this it is sometimes regarded as a security crop against times of food shortages. The main tuber, which under normal conditions is not consumed as food, can be eaten if the occasion arises. This crop is included in the intercropping model as a potential export as well as for domestic sales and domestic consumption. There are two species grown; Xanthosoma violeceum and Xanthosoma sagittifolium.

4.5.1 Xanthosoma Yields

Xanthosoma is ready for harvesting after about 12 months from planting although the longer it is left in the ground the higher the yield through the enlargement of the secondary tubers. For the analysis a traditional spacing of 0.9m x 0.9m is adopted giving an average yield of 7 tonnes per hectare per year. Weber et al (1980, pp.38) reported a yield of 13.8 tonnes per hectare at a spacing of 0.9m x 1.2m and Eisinger (1981, pp.55) estimates the yield at 14.8 tonnes per hectare at a spacing of 0.9m x 0.9m. Yields vary with the management level and the planting densities. The adopted yield was from raw data for intercropping under 25 year old coconuts at the Research Station.

4.5.2 Xanthosoma Prices

Xanthosoma is well established in the export market as well as the domestic market. Export quantities increased from 195 tonnes in 1978 to 1,496 tonnes in 1979. There is a marked fluctuation in price both in the domestic as well as the export market. Eisinger (1981, pp.55) reported a price of 16 seniti per kilogram for the domestic market and 25 seniti per kilogram for the export market. For the analysis the average price of 20 seniti per kilogram is adopted.

4.5.3 Cost of Xanthosoma Production (Table 4.10)

Although Xanthosoma is introduced in the model as both a subsistence crop and a potential cash crop, an attempt is made to evaluate all inputs and outputs. The only exception is the planting material which

TABLE 4.10

ANNUAL XANTHOSOMA CASH FLOW AND LABOUR INPUTS

I	Yield		7174 Kg/Ha
	Price		20 seniti/Kg
	Gross Revenue		T$1,434.80
II	Costs (T$)		
	(A) Production Cost		
	Tractor cultivation	10 hrs @ 11.00	110.00
	Planting materials		10.00
	Labour is costed at 4.00 per manday		
	(i) Clearing	1 manday	4.00
	(ii) Lining and holing	2 mandays	8.00
	(iii) Planting	8 mandays	32.00
	(iv) Weeding	46 mandays	184.00
	Subtotal		348.00
	(B) Harvesting Costs		
	(i) Labour	20 mandays	80.00
	(C) Marketing Costs		
	(i) Processing	4 mandays	16.00
	(ii) Selling	6 mandays	24.00
	(iii) Others		180.00
	Subtotal		220.00
	Total Costs		T$648.00
	Net Revenue		T$786.80
	Total labour requirement		87 mandays
	At 6 per cent discount rate the:		
	(i) SNPV		731.09
	(ii) SNPV per labour day		8.46
	(iii) Amortized value per year		774.96

are freely available either from a previous crop or from other farmers. A nominal cost of T$10.00 is adopted to cover any transportation expenses.

Clearing cost is limited to one manday which is required to prepare the land for tractor cultivation. This requires 10 hours at T$11.00 per hour.

Lining, holing and planting is estimated to require 10 mandays. This includes the collection and preparation of the planting materials.

It is assumed that weeding is done during the first 7 months with a total labour requirement of 46 mandays.

Harvesting includes the lifting of the tubers using either a digging fork or a digging spade and transporting them to the farmer's home. This requires 20 mandays (Appendix F, Table F.1).

Processing is estimated to require 3.5 mandays. This includes the removal of roots and dirt from the side tubers and either transportation to the packing centre and packed into 25 kilogram cases supplied by the marketing authority or transportation to the domestic market (Appendix F, Table F.1).

Selling which requires 6 mandays involves the actual sale at the domestic market (Appendix F, Table F.1).

Generally, fertilizer and chemicals are not applied in Xanthosoma production so these are not included in the model.

It is assumed that 2,025 kilograms of the yield are exported. Export costs include 81 cases at T$1.75 per case, Commodities Board export income levies of 7.5 per cent, transport costs and space rentals at the domestic market. The marketing costs are estimated at T$180.00.

4.5.4 Xanthosoma Fixed Costs

The fixed costs for Xanthosoma production is limited to basic tools. These are presented in Appendix B, Table B.1.

4.5.5 Xanthosoma Cash Flow

The costs and returns information for Xanthosoma is summarised in Table 4.10. At a 6 per cent discount rate the SNPV is T$731.09 and the SNPV per labour day is very high with a value of T$8.46 when compared to the adopted wage rate of T$4.00/day. The labour requirement per crop is 87 mandays.

The total production cost is T$348.00 of which T$228 (66 per cent) is attributed to labour. The total costs per hectare is T$648.00 of which T$348.00 (54 per cent) is labour cost, T$110.00 (17 per cent) is tractor cost and T$190.00 (29 per cent) is the transport, materials and Board levies costs.

4.6 Capsicum - Capsicum annum

Capsicum, like all vegetables, are not very shade tolerant. It is best grown as a monocrop and may give better yield when grown in areas where coconuts are widely spaced (18m x 9m). It is introduced in the model solely as a cash intercrop under coconuts. This is the shortest term crop considered in the model.

New Zealand is the main export market and is prepared to accept about 400 tonnes of capsicum between August and December.

4.6.1 Capsicum Yield

Yields vary depending on the planting density, variety planted and the management level adopted. Weber et al (1980, pp.32) reported a yield per crop of 5-12 tonnes per hectare at a spacing of 1.2m x 0.4m. They assume that this high yield is obtained when capsicum is grown as a monocrop with a high level of management.

For the analysis, intercropping data for capsicum under coconut is adopted. The raw data from the Research Division reported a yield of

1.94 tonnes per hectare per crop at a spacing of 1.8m x 0.6m. As the duration of the crop from planting to the completion of harvesting is about 5 months, it is assumed that two crops are planted annually.

4.6.2 Capsicum Prices

The price fluctuation is high both in the domestic and export market. Weber et al (1980, pp.33) reported an average export price of 40 seniti per kilogram and a domestic price of 60 seniti per kilogram for 1979. Eisinger (1981, pp.82) reported an average domestic price of 90 seniti per kilogram and an export price of about 60 seniti per kilogram. This shows that the domestic prices are far above the export prices. However, the domestic demand is very limited. For the analysis, a producer price of 70 seniti per kilogram is adopted.

4.6.3 Cost of Production (Table 4.11)

Two mandays are required for preparing the land for tractor cultivation. For two crops a year, tractor cultivation requires 16 hours at T$11.00 per hour.

Planting materials (seeds) are estimated at 0.56 kg/ha at T$32.24 per kilogram. This is the requirement for two crops.

Lining, holing and planting are estimated to require 26 mandays. This includes raising the seedlings in the seedbed, transplanting and watering.

Weeding, which is estimated to require 27 mandays per crop, accounts for the highest labour requirement with regards to any particular activity. It is assumed that two weedings are carried out every month.

Harvesting involves the picking of mature capsicums. This requires 10 mandays per crop and is spread out in the last two months (Appendix F, Table F.1).

TABLE 4.11

ANNUAL CAPSICUM CASH FLOW AND LABOUR INPUTS

I	Yield		3946 Kg/Ha
	Price		70 seniti/Kg
	Gross Revenue		T$2,762.20
II	Costs (T$)		
	(A) Production Cost		
	Tractor cultivation	16 hrs @ 11.00	176.00
	Planting materials	0.56 kg @ 32.24	18.06
	Pesticides		240.00
	Fertilizer		236.00
	Labour is costed at 4.00 per manday		
	(i) Clearing	2 mandays	8.00
	(ii) Lining and holing	10 mandays	40.00
	(iii) Planting	16 mandays	64.00
	(iv) Weeding	54 mandays	216.00
	(v) Fertilizer application	6 mandays	24.00
	(vi) Pest control	32 mandays	128.00
	Subtotal		1150.06
	(B) Harvesting Costs		
	(i) Labour	21 mandays	84.00
	(C) Marketing Costs		
	(i) Processing	11 mandays	44.00
	(ii) Selling	5 mandays	20.00
	(iii) Others		690.00
	Subtotal		754.00
	Total Cost		T$1988.06
	Net Revenue		T$774.14
	Total labour requirement		157 mandays
	At a 6 per cent discount rate the:		
	(i) SNPV		721.97
	(ii) SNPV per labour day		4.60
	(iii) Amortized value per year		765.29

Processing involves transporting the produce to the packing centre and packing into 5 kilogram cases supplied by the marketing authority. This is estimated at 5 mandays per crop (Appendix F, Table F.1).

Selling includes transportation to the domestic market and the actual time taken for the sale. This requires 2 mandays per crop (Appendix F, Table F.1).

Fertilizer is applied in accordance with the recommendation of Weber, et al (1980, pp.33). A total of 100 kilograms of nitrogen (Ürea), costing T$61.00 and 50 kilograms of Potassium (Potassium chloride) and 50 kg of phosphorous (Superphosphate) both costing T$57.00 are applied per crop. Application requires 3 mandays per crop.

For a good yield it is essential that pesticide is applied to prevent pests and diseases. Fumigation of the seed bed is carried out using methyl bromide. To control nematodes, 10 kilograms of Furidan 10% is applied. Other chemicals includes 7 kilograms of Carbaryl 80WP, 7 kilograms of Manzate 200WP and 4 kilograms of Copper Oxychloride. The total cost of chemicals is estimated at T$120.00 per crop. The application of the chemicals is estimated to require 16 mandays per crop.

Marketing is expensive especially with regards to the export market. For the analysis it is assumed that all the production is exported. The export costs includes 789 cartons at 60 seniti per carton, Commodities Board levies on export earnings of 7.5 per cent and transportation costs. These costs are estimated at T$690.00 per year or T$345.00 per crop.

4.6.4 Capsicum Fixed Costs

The fixed costs for capsicum is limited to basic tools and is presented in Appendix B, Table B.1.

4.6.5 Capsicum Cash Flow

The information about cost and return is summarised in Table 4.11.

At a 6 per cent discount rate, the SNPV is T$721.97 and the SNPV per labour day is T$4.60 which is just above the adopted wage rate of T$4.00. The labour use over the whole year is 157 mandays.

The total production cost is T$1,150.06 of which T$480.00 (42 per cent) is labour cost and T$670.06 (58 per cent) is direct cash cost.

4.7 Kava Tonga - Piper methysticum

Kava plantings are widely distributed throughout the Tonga group. The main market is the domestic market although export markets includes neighbouring South Pacific countries and in the Western European countries where it is used for pharmaceutical purposes. Kava, which is a non-perishable crop, is grown under coconuts. It is included in the model solely as a cash crop. The roots and stem base are the main products. These are crushed into powder and used for ceremonial or social drinks.

4.7.1 Kava Yield

Kava takes at least 4 years to mature enough for harvesting and to return a good yield. The analysis assumes a 5 year period. The data adopted for the analysis was obtained from the Research Division. Kava was grown under 25 year old coconuts with a spacing of 9m x 9m. With a wider spacing of coconut trees, the kava yield can be increased with increasing planting densities. Kava is planted at a spacing of 1.2m x 0.5m and yields about 10 tonnes per hectare (10,161 Kg/Ha).

4.7.2 Kava Prices

The price used in the analysis was the price prevailing in Tonga in 1981 for unprocessed kava. This is also the price adopted by the Research Division, that is, 80 seniti per kilogram.

4.7.3 Cost of Production (Table 4.12)

As kava is grown as a cash crop, all the inputs are costed and outputs priced.

The major cost in land preparation involves tractor cultivation. This requires 8 hours at T$11.00 per hour. Two mandays are required to prepare the land for the tractor cultivation.

Planting materials are valued at T$94.00 although they are mostly available free of charge. Planting materials are priced at 10 seniti per stem. One stem will provide enough planting material for three mounds.

Lining, holing and planting requires 42 mandays. This includes the collection and preparation of planting materials.

Weeding task requires the highest labour requirement. This amounts to 401 labour days per crop. This may seem high. Individual farmers may be able to use less labour to obtain the same yield.

Sixty mandays are required for mounding. This involves the heaping of soils at the base of the stem to encourage root and stem base development.

Harvesting includes the uprooting of kava, cutting off the tops, removing most of the soils and transporting to the farmer's home. This is estimated to take 40 mandays (Appendix F, Table F.1).

Processing requires 20 mandays. This includes the cleaning of stems and roots with water, cutting up the product for quicker drying in the sun, and the time taken to dry the product (Appendix F, Table F.1).

Selling which is estimated to take 10 mandays involves the time taken for the actual sale (Appendix F, Table F.1).

There is no application of either fertilizer or pesticides as this is the traditional method adopted by the Tongan farmers.

TABLE 4.12

ANNUAL KAVA TONGA CASH FLOW AND LABOUR INPUTS

Y	1	2	3	4	5
Yield (Kg/Ha)	0	0	0	0	10161
Price	0.80	0.80	0.80	0.80	0.80
Gross Revenue	0	0	0	0	T$8128.80
Cost (T$)					
(A) Production Costs					
Tractor cultivation	88	0	0	0	0
Planting materials	94	0	0	0	0
Labour					
(i) Clearing	8	0	0	0	0
(ii) Lining & holing	68	0	0	0	0
(iii) Planting	100	0	0	0	0
(iv) Weeding	416	372	340	436	40
(v) Pruning	76	68	68	28	0
Subtotal	850	440	408	464	40
Total Production Cost					T$2202.00
(B) Harvesting Costs					
Labour	0	0	0	0	168.00
(C) Marketing Costs					
Labour					
(i) Processing	0	0	0	0	80.00
(ii) Selling	0	0	0	0	40.00
Total Cost					T$2490.00
Net Revenue					T$5638.80

Total labour requirement	579 mandays
Average annual labour requirement	116 mandays
At a 6 per cent discount rate the:	
(i) SNPV	T$4052.71
(ii) SNPV per labour day	T$ 7.00
(iii) Amortized value per year	T$962.10

4.7.4 Kava Tonga Fixed Costs

The fixed costs are limited to basic tools which is given in Appendix B, Table B.1.

4.7.5 Kava Tonga Cash Flow

The information about costs and returns are summarised in Table 4.12. At a 6 per cent discount rate the SNPV is T$4,052.71, SNPV per labour day is T$7.00 and the amortized value is T$962.10. The major cost of production is the labour cost which accounts for about 92 per cent or T$2,020.00. Materials cost is T$182.00 (8 per cent). A total of 579 labour days is required.

4.8 Banana - Musa spp.

The banana industry is subsidised by both the New Zealand and the Tongan Government. This subsidy is in two parts. Firstly, both chemicals and fertilizers are supplied free of charge and secondly the export price is subsidised. The analysis is presented assuming that all inputs are costed. Banana is grown mainly for export so the cash flow is based on the production of export quality bananas of the Cavendish variety.

4.8.1 Banana Yields

The only reliable data about the yield is the export data. Most if not all of the banana farmers do not keep any records of their total production. The writer is not aware of any survey done whereby the banana production has been estimated in the field for a number of farmers. Banana production varies considerably according to the level of management and the spacing adopted. An experimental trial at the Research Station which was started in 1974 gave the following results. For the parent crop the yield was 1,116 cases (27,900 Kg) per hectare, first follower crop, 1,630 cases (40,750 Kg) per hectare and second follower crop, 978 cases (24,450 Kg) per hectare. The marked decrease in year three was due to a severe drought in

1977. The crop was planted at a spacing of 3.3m x 1.8m as a monocrop (Banana Working Committee, 1979, pp.42).

For the present analysis, assuming that the banana is grown as an intercrop, the following yield stream is adopted (Table 4.13).

TABLE 4.13

BANANA YIELD PER CROP

Year	Yield Per Hectare (Cases)	Yield Per Hectare (Kg)
1	0	0
2	874	21872
3	1098	27788
4	976	24700
5	874	21872
6	732	18524
7	488	12342

Dean and Sorrenson (1980) reported an average yield of 1,092 cases (27,300 Kg) per hectare as their assumption for their economic analysis.

4.8.2 Banana Prices

Up to July 1978 virtually all bananas shipped to New Zealand returned to the grower T$1.70 per 25 kilogram case. During 1977 the price was increased to T$2.50 for Grade A bananas. This was made possible by a bonus payment of 80 seniti per case by the New Zealand Government. In 1978 the Tonga Commodities Board decided to increase the price per case by 80 seniti. This means that growers get T$2.50 per case for non-bonus bananas and T$3.30 per case for bonus bananas. The price varies with the quality. As most export bananas fall in the non-bonus category, the price of T$2.50 per 25 kilogram case is adopted.

4.8.3 Cost of Banana Production (Table 4.14)

The following input requirements are based on the reports by Dean and Sorrenson (1980) and the Banana Working Committee (1979).

Two mandays are required for clearing the land in preparation for tractor cultivation. To cultivate one hectare, 8 hours of tractor cultivation at a cost of T$11.00 per hour is required.

Planting materials are estimated to cost 5 seniti each. This includes the cost of transportation. The planting materials are costed for the analysis although they may be available free of charge from previous crops or from other farmers.

Lining, holing and planting requires a total of 36 mandays. Holing is assumed to be done by hand and planting includes the collection and preparation of the planting materials. Dean and Sorrenson (1980) compared the use of weedicides and hand weeding as means of weed control. They concluded that there was very little difference between the two methods. For the analysis, hand weeding with a bush hoe is adopted. The total labour requirement for 7 years is 195 mandays.

Propping is essential for the banana plant which require support as the bunch weight increases. Dean and Sorrenson (1980) estimate that 330 sticks at 25 seniti each is required per year. Propping includes the collection of the sticks and propping the bunch. This requires 8 mandays per year starting in year two.

The harvesting labour requirement varies with the yield as do the processing and selling requirements. Harvesting includes the cutting down of the banana bunches and transportation to the packing centre. Processing includes the separation of the banana fingers, washing in water, and packing in 25 kilogram cases supplied by the marketing authority. Selling involves the actual sale of export rejects at the domestic market. For the analysis

TABLE 4.14

NON-SUBSIDIZED BANANA CASH FLOW AND LABOUR INPUTS

Year	1	2	3	4	5	6	7
Yield (Kg/Ha)	0	21872	27788	24700	21872	18524	12342
Price/Kg	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Gross Revenue	0	2187.2	2778.8	2470	2187.2	1852.4	1234.2
Cost (T$)							
(A) Production Costs							
(i) Materials							
(a)Planting Materials	81	0	0	0	0	0	0
(b)Hire of Machinery	88	0	0	0	0	0	0
(c)Sticks(Propping)	0	82.5	82.5	82.5	82.5	82.5	82.5
(d)Fertilizer	153.76	255.75	255.75	255.75	255.75	255.75	255.75
(e)Pesticides	482.4	576.9	576.9	576.9	576.9	576.9	576.9
Material Cost	805.16	915.15	915.15	915.15	915.15	915.15	915.15
(ii)Labour							
(a)Clearing	8	0	0	0	0	0	0
(b)Lining & Holing	68	0	0	0	0	0	0
(c)Planting	76	0	0	0	0	0	0
(d)Weeding	228	96	96	96	96	96	72
(e)Fertilizing	16	24	24	24	24	24	24
(f)Pest Control	132	160	160	160	160	160	132
(g)Propping	8	32	32	32	32	32	32
Labour Cost	536	312	312	312	312	312	260
Total Cost of Production	1341.16	1227.15	1227.15	1227.15	1227.15	1227.15	1175.15
(B) Harvesting Costs							
(i) Materials & Transport	0	240	320	240	240	160	110
(ii)Labour	0	96	128	112	96	80	56
Total Cost of Harvesting	0	336	448	352	336	240	166
(C) Marketing Costs							
(i) Labour							
(a)Processing	0	208	240	208	176	144	120
(b)Selling	0	32	32	32	32	16	16
Total Marketing Cost	0	240	272	240	208	160	136
TOTAL COST	1341.16	1803.15	1947.15	1819.15	1771.15	1627.15	1477.15
NET REVENUE	-1341.16	384.05	831.65	650.85	416.05	225.25	-242.95

Total labour requirement	1116 mandays
Average annual labour requirement	160 mandays
At a 6 per cent discount rate the:	
(i) SNPV	T$1283.67
(ii) SNPV per labour day	T$ 1.15
(iii) Amortized value per year	T$229.95

it is assumed that the labour requirement for harvesting is 163 labour days, processing is 305 mandays and selling is 40 mandays (Appendix F, Table F.1).

Urea is the only fertilizer applied in the first year. Dean and Sorrenson (1980) recommended the application rate of 38 grams per plant per quarter. The total requirement at a planting density of 1,630 plants per hectare is 248 kilograms per year. Urea is costed at 62 seniti per kilogram giving a total cost of T$153.76. From year two to year seven only NPK mixture (10:5:20) is applied. The application rate is 95 grams per plant with three applications per year amounting to 465 kilograms per hectare per year. The NPK is costed at 55 seniti per kilogram giving a total cost of T$255.75 per year. Fertilizer application requires one manday per quarter.

Harvesting costs also include the cost of transportation and rubber foam pads used as cushions for banana bunches during harvesting.

Pest and disease control constitutes one of the major costs in banana production. Corms are trimmed and dipped in a chemical mixture of Benlate, Dithane, Lepidex and Nemagon. This mixture is estimated to cost T$14.00. The first nematode control involves the application of Furidan 10% in every hole at a rate of 10 grams per hole. This is estimated to cost T$52.16. The control of Black Leaf Streak requires 8.72 kilograms of Benlate at T$28.00 per kilogram and 151.3 litres of misting oil at 68 seniti per litre every year. This gives an annual cost of T$346.16 per hectare except for the first year when application starts after two months from planting. It is assumed that spraying is done fortnightly. Further nematode control involves two applications of Furidan 10% in the second and fourth quarter of the first year and three applications per year from year two to year seven. The application rate is 20 grams per plant. This requires 34.0 kilograms per application. At T$3.20 per kilogram, this is valued at T$108.00 per application. For scab moth control, it is estimated that 5 litres of Lepidex are required per year at a cost of T$20.00.

Although the Ministry of Agriculture Forests and Fisheries is carrying out the spraying program, some farmers prefer to do their own. For effective pest control, it is best that farmers should do their own sprayings to ensure that it is done at the right time. Therefore, a mist blower is budgeted for in the fixed costs. The labour requirement for Bunchy Top control, which involves the removal of the diseased affected plants, is included in the weeding requirement.

4.8.4 Banana Fixed Costs

The fixed costs for banana is limited to basic tools and is given in Appendix B, Table B.1.

4.8.5 Banana Cash Flows

The information about costs and returns are summarised in Table 4.14. On the average about 25 per cent of the cost of production is attributed to labour cost. At a 6 per cent discount rate the SNPV is T$1,283.67 and the SNPV per labour day is T$1.15 which is very low in comparison to the adopted wage rate of T$4.00 per manday. The amortized value, which reflects the annual returns, is T$229.95 per year. A total of 1,116 mandays is required per crop or an average of 159 mandays per year.

The very low return to labour and amortized value gives an indication of the importance of the subsidies in the industry.

The 7th year gives negative return (net revenue) indicating that production should be cut off at the end of the 6th year.

4.9 Vanilla - Vanilla fragrans

Vanilla is a perennial crop lasting for about 15 years. It is a shade tolerant crop and is suited for intercropping under coconuts. Vanilla is grown as an export crop. It is a high value, low weight non-perishable crop thus it is suitable for growing in the outer islands of the Tonga group which experience irregular shipping schedules.

4.9.1 Vanilla Yields

The figures adopted for the analysis are reported by Fa'anunu (1981). The vanilla yields differ according to the management practices. One of the important components of vanilla production cost is pollination which has to be done by hand. Vanilla is planted at a spacing of 1.9m x 2.5m with an average yield as follows (Table 4.15).

TABLE 4.15

VANILLA YIELD PER CROP

Year	0–3	4	5	6	7	8	9	10	11	12	13	14	15
Yield(Kg/ Ha) Cured	0	70	210	419	489	559	559	419	349	279	210	140	70

Source: Fa'anunu (1981).

4.9.2 Vanilla Prices

Tonga is a price taker in the world market. Tollier (1980, p.2) estimated the world consumption at 3,000 tonnes and Van Dawen (1981) estimated consumption at 2,000 tonnes. The production of vanilla in Tonga in cured form was 9 tonnes in 1977, 8 tonnes in 1978, 2 tonnes in 1979 and 7 tonnes in 1980 (estimated). Van Dawen (1981) estimated the price of cured vanilla at US$40.00/Kg CIF in 1982. The net producer price given by Fa'anunu of T$22.10 per kilogram is adopted. Van Dawen (1981) predicted that

Tonga could produce up to 100 tonnes without significantly affecting the world price.

4.9.3 Cost of Vanilla Production (Table 4.16)

Two mandays are required to prepare the land for tractor cultivation which totals 12 hours at T$11.00 per hour.

The planting material requirement includes 2,700 support trees [Fiki-Jatropha curcas and Physic nut (Euphorbiaceae)] at 5 seniti each and 3,064 vanilla vine cuttings at 15 seniti each.

Other establishment costs include the transportation of both the fiki and the vanilla. This is estimated to cost T$50.00. Fencing of one hectare is estimated to cost T$270.00.

Lining and holing requirements are estimated at 8 mandays while planting requires 28 mandays. Planting includes the collection and preparation of both the support trees and the vanilla cuttings.

Weeding is done three times a year requiring 6 mandays per weeding. The weeding process begins just prior to the planting of the vanilla cuttings.

Generally no fertilizer or chemicals are applied in vanilla production and this is adopted in the analysis.

Mulching, looping and pruning is done three times a year. The labour requirement for this process is estimated at 33 mandays per hectare per year.

Pollination, which constitutes the second major labour requirement, varies from year to year depending on the number of flowers and the vigour of the vines. This ranges from 22 mandays in the third year to 89 mandays in the eighth year and 15 mandays in the fourteenth year.

Harvesting requirement varies with the yield. The yield increases up to the nineth year and then decreases. The harvesting labour requirement increases from 4 mandays in the fourth year to 31 mandays in the eighth year

TABLE 4.16

ANNUAL VANILLA CASH FLOW AND LABOUR INPUTS

Y	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Yield (Kg Cured/Ha)	0	0	0	70	210	419	489	559	559	419	349	279	210	140	70
Gross Revenue	0	0	0	1547	4641	9259	10807	12354	12354	9260	7713	6166	4641	3094	1547
Costs (T$)															
(A) Production Cost															
(a) Materials															
(i) Planting Materials	579	15	0	0	0	0	0	0	0	0	0	0	0	0	0
(ii) Hire of Machinery	132	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(iii) Fencing & Transport	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	452	15													
(b) Labour															
(i) Clearing	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(ii) Lining & Holing	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(iii) Planting	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(iv) Weeding	84	96	96	96	96	96	96	96	96	96	96	96	96	96	64
(v) Mulching, Pruning & Pollination	24	132	220	308	488	488	488	488	368	368	312	252	220	192	88
	260	228	316	404	584	584	584	584	464	464	408	348	316	288	152
Total Production Cost	1291	243	316	404	584	584	584	584	464	464	408	348	316	288	152
(B) Harvesting Cost															
Labour	0	0	0	16	48	92	108	124	124	92	76	60	48	32	16
(C) Marketing Cost															
(i) Materials	0	0	0	180	180	180	180	180	180	120	120	60	60	60	0
(ii) Curing Labours	0	0	0	108	212	372	424	480	480	372	320	268	212	160	108
	0	0	0	288	392	552	604	660	660	492	440	328	272	220	108
Total Cost	1291	243	316	708	1024	1228	1296	1368	1248	1048	924	736	636	540	276
Net Revenue	-1291	-243	-316	839	3617	8031	9511	10986	11106	8212	6789	5430	4005	2554	1271

Total labour requirement	2524 mandays
Average annual labour requirement	168 mandays
At a 6 per cent discount rate the:	
(i) SNPV	T$43361.26
(ii) SNPV per labour day	T$17.18
(iii) Amortized value per year	T$4464.60

then decreases again to 4 mandays in the fifteenth year. Harvesting includes the picking of the vanilla beans and transporting to the curing sheds (Appendix F, Table F.1).

Processing or curing involves the drying up of the vanilla beans using both the sun and the shade. This process varies with the yield and also because harvesting is spread out over a two month period. As yield increases more labour is required for processing (Appendix F, Table F.1).

There is also material costs involved in curing. This includes the purchase of wrappers, preferably blankets, used in the drying process. This is estimated at 72 metres per year costing T$2.50 per metre.

4.9.4 Fixed Costs in Vanilla Production

This is limited to basic tools and is presented in Appendix B, Table B.1.

4.9.5 Vanilla Cash Flow

The farmer starts earning cash from vanilla in year four and continues to year 15. The information about costs and returns is summarised in Table 4.16. At a 6 per cent discount rate the SNPV is T$43,361.26 and the return to the labour is very high at a SNPV per labour day of T$17.18. This is about 4 times higher then the adopted wage rate of T$4.00 per day. The total labour requirement per crop is 2,524 mandays or 168 mandays per year.

The production cost is T$7,030 of which T$5,984.00 (85 per cent) is attributed to labour costs. The total cost for one hectare is T$12,882.00 of which T$10,336.00 (80 per cent) is labour cost.

4.10 A Comparison of Cash Flows

After discussing the individual crops, to be considered in modelling and their cash flows, we can now compare the results obtained (Table 4.17). In comparison, the amortized value is looked at first. It

TABLE 4.17

COMPARATIVE DATA FOR DIFFERENT CROPS

Crop Name	Amortized Value (T$)	SNPV Per Labour Day (T$)	Total Cost Annual Average (T$)	Percentage of Labour in Total Cost	Annual Labour Use (Mandays)
Coconuts	-54.90 -3.49	-0.83 -0.05	209.66	97	40 - 52
Cassava	946.56	8.12	555.00	78	110
Yams	1957.69	9.19	2091.40	40	201
Swamp Taro	367.35	3.71	1091.00	34	94
Xanthosoma	774.96	8.46	648.00	54	87
Capsicum	765.29	4.60	1988.06	32	157
Kava	962.10	7.00	498.00	93	116
Banana	229.95	1.15	1679.44	36	160
Vanilla	4464.60	17.18	858.80	80	168

is noted that vanilla return to land and labour is the highest while that for coconuts is the lowest. The result shows that the growing of coconuts as a monocrop is not profitable. Therefore coconut land is better utilized if intercrops are grown. The intercrops should have complementary effects to coconut. Not only this but the amortized value of the intercrop should be high in order to make cropping more profitable. Banana has a low amortized value. This reflects the importance of the subsidy. If the subsidy is removed, either the banana prices should improve or the production per hectare of good quality bananas should increase or both in order to make banana production more profitable. The amortized value for capsicum is comparable to that for Xanthosoma. However, capsicum production is more susceptible to risk in terms of weather, pest and diseases.

Secondly, we can compare the return to labour in terms of the SNPV per labour day. This demonstrates the low profitability of coconuts. Therefore, it is evident that, with intercropping, there is potential for improving the return to labour to become higher than the minimum basic wage rate of T$4.00. For the intercrops, vanilla gives the highest return to labour. Others such as yams, cassava, xanthosoma, kava also give very high return to labour. Capsicum gives a return to labour which is slightly higher than the basic minimum wage rate. However, as mentioned earlier, a slight change in product price or yields may have an adverse effect thus reducing the return to labour considerably. Swamp taro has a value which is below the basic minimum wage rate. This crop is becoming established in the export market. Therefore, an improvement in the product price will raise the return to labour above the minimum basic wage rate. The return to labour for bananas is very low. This also emphasizes the importance of the subsidy.

Thirdly, we compare the average annual total cost and labour requirement of different crops. The high costs for capsicum, swamp taro, bananas and yams reflects the high costs of planting materials, fertilizer, pesticides and marketing costs. It is interesting to note the labour requirement for each crop. This could be an important policy issue with regards to potential employment. For cassava, kava, vanilla and coconut, labour accounts for a very high percentage of the total cost. In terms of actual labour requirement, most of the crops have high labour requirement as compared to coconuts.

The next chapter will discuss the specification of the models and the assumptions and constraints involved in the modelling technique.

CHAPTER 5

MODEL SPECIFICATION

This chapter considers the development of likely cropping models that could be suitable for adoption by the farmers. The models have certain constraints such as location, land, labour and development capital. As the different cropping models will depend on the farmers objectives, there is first a discussion of the specification of objective functions. Secondly, the cropping pattern and labour availability of the large subsistence sector is considered. This will reflect the availability of land and labour for the monetary sector. Thirdly, there is a discussion of the factors affecting modelling. Lastly, the data and the assumptions adopted for modelling are discussed.

5.1 Alternative Objective Functions

The alternative specifications of the objective function has been discussed by Burgess (1981). Heady (1971) implies that the objective function may include one or more of such objectives as physical output of food, managerial utility, maximum profit, net worth or minimum variance of food and income. Becker (1965), working on the theory of allocation of time, emphasized the significance of time as a resource constraint. This lead other analysts to incorporate time in the objective function. Stryker (1976), basing the objective on the constraint that a subsistence standard equals output per capita, had the farmer maximizing his leisure. Benito (1976) saw that through the allocation of time and marketed products, the peasant household maximizes the discounted utility of expected consumption of home grown food and purchased goods.

Lipton (1967), disagrees with Shultz's argument that the smallholder in India equates marginal value product of money in each use. Lipton states that optimising behaviour is prevented by factors such as influence of customs, taste, uncertainty in weather, the dynamic effect of population growth, and law in decision-making. Therefore, he concluded that the farmer, considering his various basic needs, will adopt a survival algorithm. With regards to the Tongan context factors such as customs, weather, taste, social obligation and location also affect the objective of the farmer. If we follow Lipton's argument, then it is clear that most Tongan farmers adopt a survival algorithm rather than an optimizing algorithm. Upton (1976) also notes that even if we assume the farmer to be rational, this does little to reduce his possible set of goals or objectives. He concluded that the only clearly irrational activity is a level of present consumption that would prevent future survival. This may not be fully observed in Tonga, but if one considers the amount of feasting, which is a part of the Tongan way of life, one can conclude that there is a substantial economic waste. This may be termed an irrational behaviour because the food used in the extensive feasting could have been converted into foreign exchange earnings. Also these foods, some of which will be fed to animals, could have been used for future consumption.

A lot of attention is given in the literature to the relative merits of the use of the 'net present value' in the objective functions. This is compared to the use of the net worth concept, when used in the objective functions. The concept of maximising the SNPV is widely accepted as an extension of the static model's maximisation of profits. This takes into account the time preference in the flow of income generated by alternative investments (Burgess, 1981).

Cocks (1965) showed that given the sum of consumption and investment equals income, maximisation of the discounted profit stream is equivalent to the present value of accumulated net worth at the planning horizon plus the maximisation of the SNPV of the future stream of consumption within the planning period. This was based on the assumption that at the plan horizon, net worth is valued at its potential future contribution to generating consumption flows. Profits make no contribution to utility unless they are consumed (see Appendix D). By considering the farmer's allocation decision between investment and consumption in each period, Cocks took the above objective function one step further. Consumption was defined as luxury consumption. This was similar to the prevailing rates of return on investment. The farmer would enjoy luxury consumption if his personal discount rate was higher than the rate of return on investment. Therefore he will allocate his income accordingly. The farmer would invest if the reverse situation occurs, and he would be indifferent between consumption and investment when the rate of return for investment equalled the personal discount factor for luxury consumption. Cocks assumes that in a situation of indifference the farmer would always invest. As the discount factor will be common to all net investment, the objective function becomes the maximisation of accumulated net worth at the planning horizon (see Appendix D). This objective function is also considered in the final analysis of this study. The SNPVs at the end of each planning horizon (12 years and 15 years) are reported. These SNPVs can be considered by the farmers on a relative concept and can be used as a basis for changing the cropping pattern.

Boussard (1971), discussed the alternative objective function formulations from the point of view of the planning horizon. He adopted the Modigliani definition that the planning horizon extended until the length has no effect on the optimal decision for the first time period. Boussard observed that capital goods, with a small salvage value and a life duration longer than the planning period, were penalised in a net present value model. This is because the net present value models tended to lengthen the planning horizon beyond the Modigliani optimum. Boussard also criticised the net present value models from the mathematical aspect. He concludes that in the case of a negative discount rate the model does not guarantee the existence of a planning horizon.

Boussard (1971), assuming a linear consumption function and adopting Cocks (1965) consumption-wealth objective function, showed that maximising the terminal net worth was equivalent to maximising the stream of future consumption. Boussard used the turnpike theorem to establish a practical rule for reaching the Modigliani planning horizon. This was based on the theorem of separability of matrices. He utilized the same theorem (turnpike) to demonstrate the existence of a planning horizon when maximising terminal net worth.

Other writers have adopted different approaches when determining the planning horizon. Upton (1976), states that difficult decisions are required as to what should be left to the future once a finite planning horizon is adopted. These decisions may involve the level of terminal capital stock and how to value this residual. Knowledge of future cash flows and the opportunity cost of the capital is essential when valuing terminal capital stock. Renborg (1971) suggested that the horizon chosen was unique to particular situations. The planning horizon is influenced by the economic life of the durable assets, the decreasing economic importance of future time periods, the expected lifetime of the entrepreneur and the length of the production period.

Ogunfowora (1970) suggested that some of the main objectives for the Farm Institute Settlement Scheme in Western Nigeria includes the raising of peasants income, creating attraction in rural life, demonstrating improved farming techniques, and providing employment. However, the objective most relevant to this study was the provision of adequate income to the settlers equal to or higher than corresponding urban income. Abalu (1975) reports that farmers grow a mixture of crops not only as a risk precaution but also to stabilize income. The above objective functions should be considered before choosing one which is most appropriate to the smallholder situation in Tonga.

The use of the SNPV formulation requires the assumption of an appropriate discount rate. This should represent the time preference rate of the decision maker who is going to use the results of the model. For those with low incomes and short life expectancy, higher time preference is expected. It is possible for the decision maker to obtain his subjective evaluation of his time preference rate by considering alternative strategies with different rates of return. However, variation over time and between individuals in time preference complicates the issue even further. Thus in the case of the smallholder in Tonga, the discount rate chosen should reflect families' time preference. The discount rate may be high due to the importance of the older members of the family in the decision making process. Another alternative is the current interest rates charged for obtaining development finance. This could be adopted so that the SNPV would indicate a net return on capital from the enterprise (Burgess, 1981). Therefore, the discount rate adopted for the analysis is assumed to be that set by the development bank. Although interest rate normally varies with the time period, for the analysis, it is assumed that the market is perfect. Therefore, only one interest rate is used.

If we adopt the Cocks (1965) consumption-wealth objective function we still require the following assumptions: (a) the indifference farmer chooses to invest so that terminal net worth is maximised; (b) time preference is equal to the rate of return on investment; (c) determination of a time preference rate in the case of the multi-objective form. Terminal net worth may alternatively be maximised if a linear consumption function is assumed. However, this may raise problems in situations where income is low and fluctuates. This may lead to an assumption of less than subsistence consumption in some years.

The form of objective function chosen for this particular study is the maximisation of the SNPVs. Different intercropping models will report respective SNPVs. This formulation will enable the farmer to choose between alternative competitive uses of the resources available to him keeping in mind the constraints and his other objectives. Due to the farmers' multiple objectives the model with the highest SNPV may not always be the preferred one. As intercropping does not require large capital assets, as indicated in the last chapter, the minimising of fixed costs is of little benefit. This minimisation is important only where fixed costs are substantial and where there are alternative sources of supply. In this study, the time horizon is taken to be 12 and 15 years. Thus it is predetermined with regard to the crop production period of two of the major cash crops.

5.2 The Farm Unit in Tonga

The operation of the farm family within the farm unit is contrained by the land tenure system. The traditional customs also affect the farmer's activity on his farm. Ward and Proctor (1980) reported that generally labour is not specialized and the payment principle for some of this labour is reciprocity. Due to this the individual farmer may, in the future, depend upon those he is called upon to assist from time to time. As already mentioned earlier (Chapter 1), a large proportion of subsistence farming co-exists with a lesser proportion of commercial farming. Therefore, the first priority of most farmers is to produce to satisfy the subsistence requirements. Above this they will then produce for the market.

The operation of the land use system in Tonga is based on the tax allotment system whereby the farmer chooses the type of crops he grows. Domestically this choice is affected by his social obligations and his obligation to the nobles. The farmer's choice of export crops is affected by the cash inputs, which are substantial from the farmer's viewpoint, his locality, and his range of crop preference. Thus the sole decision maker is the head of the family, the husband. Hardaker (1973, cited in Hardaker, 1975) estimated the average size of the Tongan household for the period 1972/73. From the 1966 population census, he estimated that adult males 16 years or over per household was 1.82.

Part of the farming sector in Tonga can be defined as "Subsistence with supplementary cash production" (Fisk, 1975). In this case, the family requirements are produced mainly by the farm family which consumes the product. Apart from this, supplementary production is undertaken in order to secure access to market goods and services which may not be obtainable directly from the farm family's own resources. A lesser part of the farming sector may be defined as "Cash orientation with supplementary subsistence" (Fisk, 1975). Here the producer is oriented towards the monetary economy. His main productive efforts are directed at earning cash incomes. However, a substantial part of his food requirements and other necessities may be produced on his farm. This is because, in terms of factor costs, it is more economical to do so. An example of this are the farmers who specialize in the production of vanilla, bananas and swamp taro for the export market. The Tongan farmers commence operations in the market either by obtaining wage employment or by producing cash crops over and above their subsistence requirements.

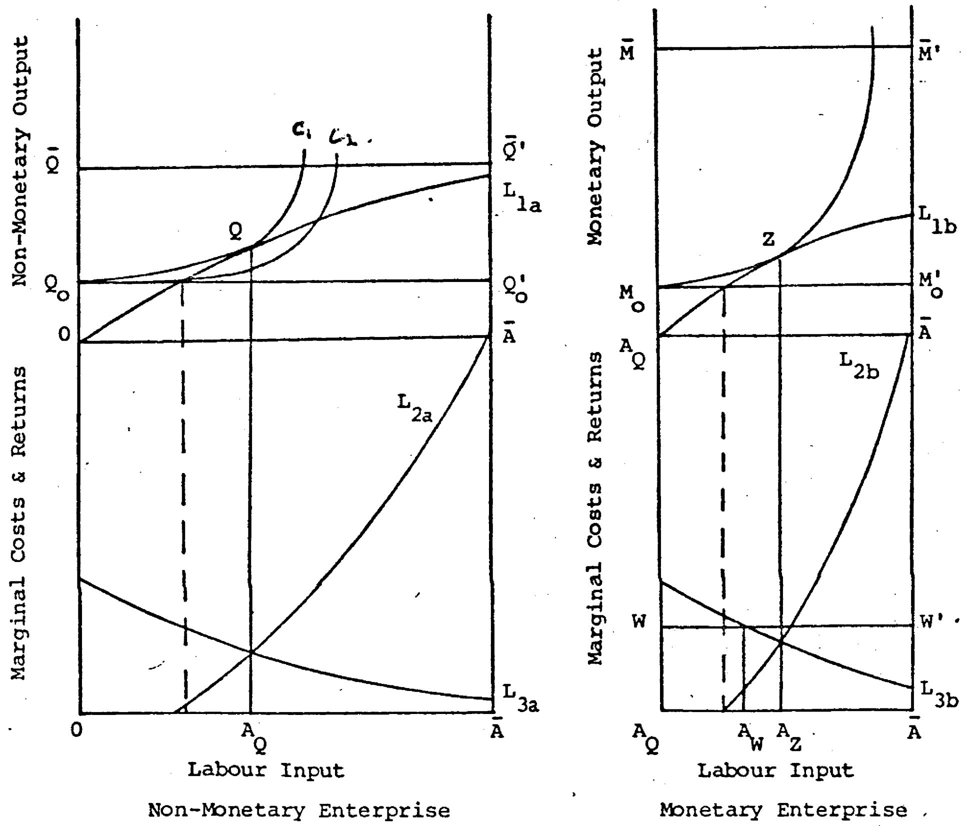
The Nakajima-Fisk models (Fisk, 1975) provides some discussion, which the writer thinks is relevant to the application of the farm family labour in Tonga. The farm family production consists of two related enterprises, one monetary and the other non-monetary. In Figure 5.1, the non-monetary activities are being discussed. OA_Q is the amount of labour used for the production of the subsistence requirement, Q. Similarly, the amount of land used can be termed B_Q where $B_Q < B$. Here, B represents the total land available. This available land is taken to be 3.34 hectares, the size of the tax allotment.

The shape of the subsistence production possibility curve, OL_{1a} is determined by the quality and quantity of land available, demographic characteristics of the family production unit and the techniques and improvements in use. The indifference curves (C_1-C_2) will be determined by the position of the subsistence line $Q_oQ'_o$ and the income (non-monetary) aspiration line $\bar{Q}\bar{Q}'$. Therefore, the supply of labour for the monetary enterprise (Figure 5.2) is thus determined indirectly by the factors discussed above, that is, by the subsistence enterprise.

The production possibility curve, A_QL_{1b} in the monetary enterprise (Figure 5.2) will be determined by the land use in the non-monetary enterprise (Figure 5.1). As a general rule, given the quality and quantity of land available, the production possibility curve in the monetary enterprise will be lower and flatter as the level of subsistence production required for equilibrium in the subsistence enterprise gets higher (assuming ceteris paribus). Conversely, a steepening and heightening of

NAKAJIMA - FISK MODEL UNDER
EXISTING CROPPING PATTERN

FIGURE 5.1 FIGURE 5.2



Source: Fisk, 1975.

the production possibility curve in the monetary etnerprise ($A_Q L_{1b}$) will occur if the aspiration level ($\bar{Q}\bar{Q}'$) of the subsistence component will be reduced. This is clearly seen in the case where the subsistence crop and the monetary enterprise crop are the same. In Tonga this occurs with regards to the root crops such as yams, xanthosoma and swamp taro. These crops are both treated as subsistence and export crops. That is, the surplus is exported.

Thus in Figure 5.1, OA_Q represents the amount of labour used in the production of the subsistence requirement, Q. A_Q-$\bar{A}$ will be the amount of labour available for the monetary enterprise. OL_{1a} is the production possibility curve while C_1-C_2 are indifference curves. Q_oQ_o' is the minimum subsistence requirement and $\bar{Q}\bar{Q}'$ is the aspiration level. L_{2a} is the marginal valuation of family labour and L_{3a} is the marginal productivity of family labour.

For Figure 5.2, the minimum income line is represented by M_oM_o'. This is essential minimum income which enables the production unit to produce. $\bar{M}\bar{M}'$ represents the aspiration income of the family unit. The wage level is represented by WW'. At this wage level, represented by the T$4.00/day minimum wage in Tonga, the labour input for on-farm cash producing activities is reduced from A_Z to A_W. Beyond A_W the family labour would attempt to get wage employment.

The high level of $\bar{M}\bar{M}'$ has also been discussed by Hardaker (1975). He concluded that the Tongans are affluent in subsistence goods. However, generally the Tongan farmers' aspirations are high but at the same time cash earnings are low.

In considering how to raise the effective participation of the combined unit in the monetary economy by stimulating the money enterprise, Fisk (1975) noted that apart from other factors -

> "The other type of intervention, much neglected in Pacific territories at least, is to raise the production possibility curve, L_{1a}, in the subsistence enterprise by improving the level of technology, using improved planting materials, and improving other inputs, such as fertilizer and water".

The effective application of the above will release more labour and land to the monetary enterprise, therefore, raising productivity in this enterprise.

Formal intercropping can be considered as a means of raising the production possibility curve of the non-monetary enterprise thereby releasing land and labour for the monetary enterprise. Not only this, but intercropping is envisaged to increase the income from the monetary enterprise. These are illustrated in Figure 5.3 and Figure 5.4. In Figure 5.3 the OL_{1a} is steeper implying that less labour (OA_Q) will be required to produce Q as compared to Figure 5.1. This releases more land and labour to be utilized in the monetary enterprise. In Figure 5.4 the production possibility curve A_QL_{1b} is steeper, therefore, more output is produced as compared to Figure 5.2. The minimum cash requirement $M_oM'_o$ is increased due to tractor cultivation, pesticide and fertilizer requirements. The minimum wage WW' will be lower than intersection point N. This is due to the higher return to labour with formal intercropping. This implies that the family unit will use less of its labour, A_QA_W instead of A_QA_Z and will have the incentive to hire in more labour A_WA_W' with potential increases in output up to Z'. Therefore, employment opportunities will be increased.

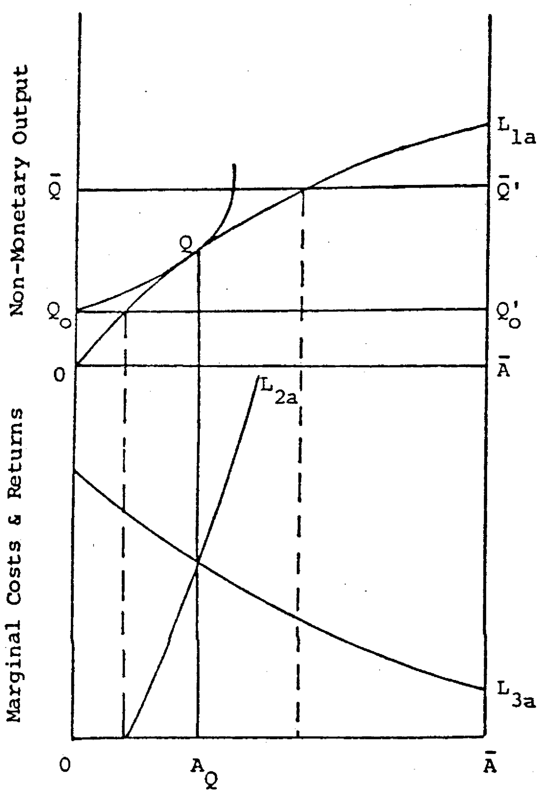
In modelling, it will be assumed that the farm family labour will be committed first to the subsistence crops with surplus to be exported.

5.3 Model Building

Most of the coconut lands in the world are monocropped. The sole coconut stands is estimated at over 75 per cent. It is evident from the amount of research done (Chapter 2) that there is a widespread interest

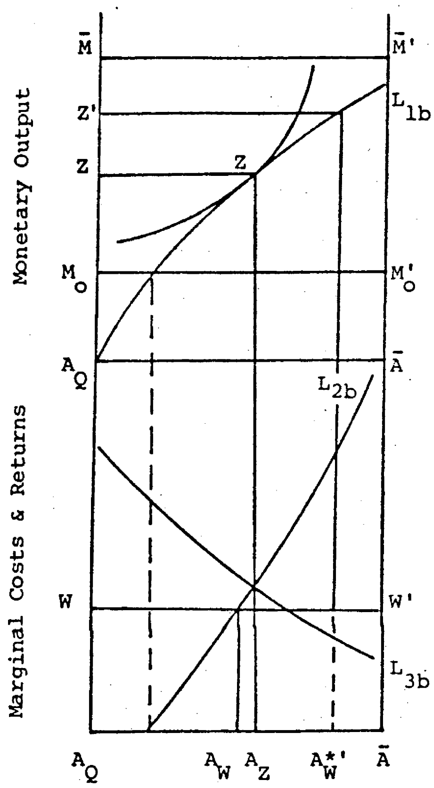
NAKAJIMA - FISK MODEL
UNDER AN INTERCROPPING SYSTEM

FIGURE 5.3



Non-Monetary Enterprise

FIGURE 5.4



Monetary Enterprise

Source: Fisk, 1975.

shown by coconut producing countries for intercropping coconuts. Etherington et al (1981) discussed a number of factors which contributes to this current interest. These include:

1) The excess pressure on types of land utilization caused by an increasing rural population. Thus the viability of an agricultural enterprise that directly employs only about one person for every 10 acres of coconut land (sole crop) is being questioned.

2) The inefficiency of sole coconut crops as converters of biological resources into dry matter equivalents per unit area. This was theoretically calculated by Nelliat et al (1974).

3) Certain intercropping systems were successful in raising both employment and productivity.

4) In an era of high energy prices, consideration is given to the relatively low purchased energy requirements of perennial crops.

5) Attempts to mimic nature through an increasing ecological awareness. This means that the crop species are grown in a mixture thus advancing towards the climax vegetation. This is done mainly in the tropics.

Factors such as those stated above creates scientific interests to design formal intercropping systems. The crops considered should be mutually compatible thereby efficiently utilizing environmental resources. There has also been a re-examination of the random mixtures of perennial crops that has been an important feature of the traditional farming system in the humid and semi humid tropics for many centuries.

In the building of intercropping models, there are four basic issues which should be considered. These are: (a) what are the crops to be planted; (b) what area is to be occupied by each crop; (c) when is the crop introduced during the life of the coconut; and (d) what are the likely interaction effects between the crops considered. Will the crops have a supplementary or complementary relationship or will they compete with each other for the biological resources? If competition occurs, then, by how much?

The importance of the above issues can be illustrated by a specific example. Let us assume that bananas are to be grown under mature coconut palms. This is the answer to the first question. Therefore, we are considering a banana - coconut intercropping scheme. The coconuts are planted at a spacing of 9m x 9m square with a planting density of 123 palms per hectare. At this planting density, it is estimated that the root system occupies about 25 per cent of the land. The next question will be related to the area planted with bananas. Do we plant the remaining area, that is, 75 per cent with bananas or do we plant less of the remaining area? There are many possible alternatives with regard to the area to be planted with bananas. Having decided on this issue, we can then decide when to plant the bananas as the banana plantation requires 7 years while the coconut time span for the MULBUD analysis is 12 years. Depending on the answers to the above questions, the banana under coconut schemes can be modified. Every modification can be referred to as a different model. The different models may have quite different implications with regard to the flow of costs and returns and the labour requirements. All these models will show different economic results.

Apart from the saving of land resources in intercropping, another major reason for the planting of intercrops is because of the potential advantage from interaction effects. Willey (1979) concluded that in terms of yields, the component crops of an intercropping system may experience neutral, complementary or inhibiting effects on each other. There are also likely to be interactive effects with regard to the use of labour. Therefore, with regards to the weeding requirements, there are likely to be some saving of labour when comparing monocrops with intercropping. The weeding requirements for intercropping systems are likely to be less. Similarly, the labour requirement for the application of fertilizer and pest control may be less than the sum of the requirements for the different crops, included in the intercropping model, when considered separately.

The present value of the future returns, discounted at an appropriate rate of interest, is the prime criterion for the economic assessment of the crop model. This is the SNPV. It is the net enterprise income, after allowing for payment to family labour and all cash expenses. However, since the period of analysis for individual sole crops varies, according to the duration of the crops' maturity, their returns will be ranked in terms of their annuities. This is represented by the amortized values. The annuities represent the constant annual equivalent of the SNPV. Other economic criteria will also be considered. These will include the return per labour day. The return to labour will give a measure of the reward to the farm family for their efforts over and above the opportunity cost of their time. Also included is the sensitivity analysis. This will reflect the relative stability of returns to fluctuations in input costs, commodity prices and yields around the expected 'best guess' estimates. The internal rates of return will also be considered.

Further criteria will have to be considered by policy makers when the final judgement is made regarding the superiority or suitability of any crop model. These would include: (a) the ease with which the models can be adopted. Therefore, models involving traditional crops are likely to need less administrative support in extension and marketing. (b) The extent to which the crop combinations meet basic subsistence requirements of the farmers and other members of the populace. (c) The employment potential of the crops. (d) The importance of the cash crops as foreign exchange earners.

The above discussion is sufficient to demonstrate that intercropping is a complex system. This is a good reason why intercropping models are not ranked in any way in this study. Furthermore, MULBUD does all the hard computational work of scaling, multiplying, adding, discounting and shifting vectors through time. This will be an extremely laborious and time consuming activity if undertaken by hand.

5.4 Data and Assumptions for Modelling

The data for the analysis were assembled from a variety of studies and reports as stated in Chapter 4. The studies done in Tonga reported data on a per acre basis. These data were converted to a per hectare basis, assuming constant returns to scale. All data were reported on a per crop basis giving annual requirements for inputs and also annual yields. These data were converted into seasonal data to conform with the MULBUD technique. For vanilla, three seasons per year is assumed, while for the other crops, four seasons is assumed. This is because the data for vanilla was from Vava'u and the rest of the data for the other crops were from Tongatapu. The assumptions were based on the agricultural calendar year, the way the data from the studies were presented, and the writer's limited knowledge of the planting and weeding times for individual crops.

For the coconut and banana crops, the seasonal production should vary. However, because of the limited information regarding the yields, and studies considered giving only annual yields, this study assumes equal yield for the four seasons. All the annual (one year duration) crops were assumed to be planted in January so that the analysis can be accommodated in MULBUD with an annual duration. However, most of the crops can be planted during any month of the year. Early planting may give better yield. The main season for yam planting extends from June to September.

All the prices are assumed to be constant, based on 1981 prices. Therefore, the rapid inflation that Tonga is experiencing has not been taken into account. There has been no assumption, with regards to the price of the products or purchased inputs, in relation to price trends or seasonal variation in prices. The hired wage rate was assumed to be constant at T$4.00 per day. Therefore it was assumed that there is no variation in the price of hired labour between the different seasons and between years. The discount rate adopted for the analysis is 6 per cent. It is assumed that the market is perfect, so a constant discount rate was used for both annual and perennial crops. Discount rates of 10 per cent and 15 per cent were used for comparison. This is illustrated in cases where the break-even price for individual crops are considered.

The farm family labour availability is assumed to be equivalent to 2 male adults. This assumption is based on Hardaker (1975). He stated that according to the 1966 census, the average household consists of about 1.82 adult males who are 16 years old or over. However, labour availability may be much higher due to the extended family system and school leavers. These people may not have a paid job or be unable to continue further education. It is assumed that each adult contributed 4 mandays per week to farming activity. This was based on the estimation by Maude (1965, cited by Hardaker, 1975) that the Tongan farmer spends 20-30 hours per week on agricultural work. Therefore, the family labour availability for the year is assumed to be, January-March (96 mandays), April-June (104 mandays), July-September (104 mandays), and October-December (96 mandays). The difference between the seasons is due to the assumption that during Christmas time (January and December), the farm family takes a two week holiday.

For Vava'u, where most of the vanilla is grown, the agricultural year is divided into three seasons only. Therefore, the family labour availability (2 male adults) is assumed to be, first season (136 mandays), second season (136 mandays), and the third season (128 mandays). This labour availability may be grossly underestimated with regards to the vanilla crop as women and children are the major part of the farm family labour force. The farm family labour is applied first to intercropping models which contain subsistence crops. The balance is then applied to cash cropping with a likelihood of employing more labourers. In all cases, the family labour input costs have been imputed at a seasonal adjusted opportunity cost. This is based on the chances of obtaining off-farm employment. The seasonal family wage adopted for the analysis are T$2.80, T$3.20, T$3.20 and T$2.80 per day for the above four respective seasons. For Vava'u, they are T$2.80, T$3.20 and T$2.80 per day for the three respective seasons. It is likely that more people will be seeking paid employment during the first and last two months of the year. This is due to the need to earn school fees and to pay for other expenses during the beginning of the year and the commitment to the Christmas feasting and high spending during the latter part of the year.

The land resource was not given any value in modelling. However, the value of the land can be reflected in the SNPV of the different crops planted. Therefore, the value of land in use for any one crop can be compared with the value of its use by the next best alternative crop in the crop model.

The crops are given a terminal value on two occasions. Firstly, when their life exceeds the period of analysis and secondly, the perennial crops are given terminal values. This represents the value of potential planting materials. The terminal value for the crop exceeding the period of analysis (coconuts) is based on the present value of amortized expected earnings beyond the terminal date. For the analysis, it is assumed that the coconut stand is sold at the end of each 12 year period. Therefore, a terminal value is estimated for each period. It is also assumed, that beginning in period two, the coconut stand is bought by the farmer in the first year. The purchase price is the same as the terminal value for the previous period. This purchase price is reflected in a high capital cost in the initial year of each period.

It is also assumed that all the coconut palms are planted at only one spacing, 9m x 9m square, with a planting density of 123 palms per hectare. With this density, the effective root zone of the coconut is assumed to occupy 25 per cent of the gross area. Therefore only 75 per cent of the land is available for planting of the intercrops. The light interception index (LII) and the land utilization factor (LUF) are also used in the analysis. This assumption is based on the findings of Nair (1979) as detailed earlier.

It is also assumed that the capital costs for crop production can be made available by the Tonga Development Bank. For banana and vanilla, capital is available via loans to cover the costs during the years where no production occurs. Other crops may require investment capital to cover establishment costs such as tractor cultivation, purchasing of planting materials and for pest and disease control. These will also be included in the modelling. The loans will be included in the model as a lump sum in the first year. A grace period will be allowed for before the loan will be paid back in equal instalments over a number of years. This payment will be based on the yearly instalment which may be decided by the bank and the loan applicant. The separate islands will also influence the type of crop mixes or models.

The next chapter will investigate the potential of different crop mixes or models in terms of their SNPV, SNPV per labour day, employment opportunities, establishment costs and other economic characteristics.

CHAPTER 6

RESULTS AND DISCUSSION

The analysis, for most of the intercropping models, is undertaken on the basis of a unit area of one hectare. However, some analyses are undertaken on the basis of a tax allotment which is 3.34 hectares. In some cases, the time period for the analysis of the intercropping models is 12 years. For the vanilla intercropping model, the analysis is undertaken over a 15 year period while the analysis of the tax allotment modelling is undertaken over a 5 year period. For all the intercropping analyses, except vanilla intercropping, each year is divided into 4 seasons with each season consisting of 3 months. For the vanilla intercropping model, each year is divided into 3 seasons with each season containing 4 months. In all the models, the crops are assumed to be planted during the first season of the year.

The analysis of the different intercropping models under coconuts seeks to highlight and compare the economic returns and labour requirements between different alternatives. These alternatives include:

(a) The growing of different perennial cash crops under coconuts.

(b) The planting of coconuts at a reduced density while at the same time increasing the density of the intercrop.

(c) The growing of different combinations of annual crops under coconuts.

(d) The growing of perennial cash crops during different times of the period of analysis.

(e) The growing of a mixture of subsistence and cash crops on a tax allotment.

The major constraints for the models include land area, labour availability, cash requirements and the light interception index. For all the models, it is assumed that a loan is available either at the beginning or during the period of analysis. The loan is estimated to either cover the establishment cost for the crop or to cover the costs during the years when there is no production. The interest and discount rates assumed for all the analyses is 6 per cent. For all the models, assumptions are made with regards to the family labour availability and the level of family and hired wage rate (detailed in Chapter 5). For the modelling of a tax allotment, an assumption is made with regards to the percentage of land occupied by each crop. It is also assumed that due to beneficial interactive effects of intercropping, the labour required for the weeding of a sole coconut stand is saved. Therefore, only the weeding requirement for the intercrops is included in the modelling.

6.1 Comparison Between Perennial Cash Intercropping

The perennial cash crops considered in these models are banana, kava and vanilla. The unit area adopted for modelling is one hectare. The time period adopted for the analysis of the banana and kava intercropping models is 12 years while that for vanilla is 15 years. The assumptions about the time of planting and gross area occupied by the individual crops are summarised in Table 6.1. In all the models, the main crop is coconut which is planted at a density of 123 palms per hectare.

For Tonga Intercropping 1A and 2A, the intercrops (banana and kava) are grown under 49-60 year old coconuts. For Vava'u Intercropping 1, the vanilla intercrop is grown under young coconuts aged between 1-15 years

TABLE 6.1

TIME OF PLANTING AND AREA OCCUPIED BY EACH CROP

Intercropping Model	Crops Grown	Percentage of the Land Utilized By the Crop	Years in Which the Crop Occupies the Land. Year to Year	
Tonga Intercropping 1A	Old Coconut 1	25	1	12
	Banana	60	1	7
	Banana	60	9	12
Tonga Intercropping 2A	Old Coconut 1	25	1	12
	Kava	60	1	5
	Kava	60	7	11
Vavah Intercropping 1	Young Coconut	25	1	15
	Vanilla	60	1	15

old. The three different models are assumed to represent the normal planting of one hectare of banana, kava and vanilla respectively under coconuts.

For the banana and kava intercropping models, it is assumed that one year is left fallow between each crop. During this fallow period, legume seeds are broadcast to help replenish soil fertility. There is no weeding during the fallow period. The return for a vanilla crop grown under any time period of the life of coconuts is much higher than that for either kava or bananas. Therefore, it does not matter which time period is chosen for the comparison.

The costs and returns for the above intercropping models are summarised in Appendix G, Table G.1 to Table G.3. The results from these tables are then summarised in Table 6.2 for comparative purposes.

TABLE 6.2

RETURNS, LABOUR REQUIREMENT AND LOANS FOR PERENNIAL CASH CROP INTERCROPPING

	Tonga Intercropping 1A (Banana)	Tonga Intercropping 2A (Kava)	Vava'u Intercropping 1 (Vanilla)
SNPV (T$)	3492.84	8165.99	45272.78
Amortized Value Per Year (T$)	416.62	974.01	4661.41
SNPV Per Labour Day (T$)	1.66	5.56	13.56
Average Annual Labour Requirement (mandays)	175	123	223
Loans (T$)	1400	600	2000
Grace Period (Years)	1	4	3
Repayment Period (Years)	4	1	4

Under the assumptions made for the individual crops and for modelling, we can conclude that vanilla is the most profitable crop to be grown under coconuts. In terms of the return to labour, the vanilla intercropping model has the highest SNPV per labour day followed by the kava intercropping model. The SNPV per labour day for the banana intercropping model is much lower than the adopted hired wage rate of T$4.00. It is also lower than the lowest family wage rate of T$2.80. Therefore, according to the Nakajima-Fisk model described in Chapter 5, the farmer will not be willing to grow bananas but will use his labour in a more profitable venture. Thus, if the banana subsidy is removed while the product price and yield remain constant, the production of bananas for the export market will be unprofitable.

If we compare the amortized value, which reflects the average annual return, we note that the value for the vanilla intercropping model is about 5 times as high as the value for the kava intercropping model and about 10 times as high as the value for the banana intercropping model.

There is also a marked difference in the labour requirement for the different models. Vanilla intercropping employs about 100 mandays per hectare per year more labour than kava intercropping and about 48 mandays more than banana intercropping. Therefore, vanilla also has the added advantage of potential employment opportunities.

Another important feature to be considered is the sensitivity of the models to changing material costs, product prices and yield. This is an important issue as Tonga imports material inputs such as fertilizers and pesticides and therefore has no control over rising prices. Also, Tonga is a price taker in the export market with regards to vanilla, copra and bananas and therefore price fluctuation is out of its control. The product prices for the other crops are almost certainly determined by the size of Tonga's export, so the product price could be controlled by controlling the amount of exports.

The sensitivity analysis will reflect the susceptibility of different crops to changing prices, costs and yields. It is hard to interpret the sensitivity analysis for a model as the changes which occur in relation to material costs or gross revenue could be a result of a combination of many factors. However, we can investigate the sensitivity of the SNPV of different crops to changing costs and returns. This can then be used as a basis for selecting intercrops. A change in gross revenue could be due to either a change in price, yield or a combination of both. Labour will be assumed to remain constant except for coconut where labour is saved when intercropping. For a banana sole crop (Table 6.3), a 10 per cent increase in gross revenue will result in about 80 per cent increase in the SNPV. Therefore, a slight increase in the product price or yield will turn banana production from an unprofitable venture to a profitable one. A 10 per cent increase in material cost will result in a

TABLE 6.3

:ROP: TONGA BANANAS AREA UNIT: Hectare

S E N S I T I V I T Y A N A L Y S I S

Sensitivity Analysis on Discount Rates

SNPV = 1148.99 at a Discount Rate of 8.00
SNPV = 712.84 at a Discount Rate of 16.00
SNPV = 398.61 at a Discount Rate of 24.00
SNPV = 167.39 at a Discount Rate of 32.00

Sensitivity Analysis of Costs and Returns

SNPV in T$ at 6.00 percent per annum

Horizontal axis = % change in MATERIAL COST
Vertical axis = % change in GROSS REVENUE

20.0 %	10.0 %	0.0 %	-10.0 %	-20.0 %	
2272.66	2800.53	3328.39	3856.26	4384.13	20.0%
1250.30	1778.16	2306.03	2833.90	3361.76	10.0%
227.93	755.80	1283.67	1811.53	2339.40	0.0%
-794.43	-266.57	261.30	789.17	1317.03	-10.0%
-1816.80	-1288.93	-761.06	-233.20	294.67	-20.0%

41 per cent decrease in SNPV. If material cost were to increase by 10 per cent and gross revenue were to decrease by 10 per cent, the SNPV will be negative at -T$266.57. Therefore, a slight unfavourable outcome will result in a negative return to the industry. Thus banana production is very sensitive to changes in both costs and returns.

For a kava crop, if the gross revenue increases by 10 per cent, the SNPV will increase by 15 per cent. A 10 per cent increase in material cost will result in less than 1 per cent decrease in SNPV. If gross revenue were to decrease by 10 per cent and material costs were to increase by 10 per cent, the SNPV will decrease by 16 per cent (Table 6.4). The kava production is not sensitive to changes in material costs. This is due to the fact that the cost of production is composed mainly of labour costs as discussed in Chapter 4.

For the coconut crop, a 10 per cent increase in gross revenue will result in about 36 per cent increase in the SNPV while a 10 per cent increase in material cost will result in 12 per cent decrease in SNPV. If gross revenue were to decrease by 10 per cent and material costs were to increase by 10 per cent, the SNPV will decrease by 49 per cent (Table 6.5). It is interesting to note here that with intercropping, the labour requirement for weeding of a sole coconut stand will be saved, therefore the gross revenue will automatically increase.

For the vanilla crop, a 10 per cent increase in the gross revenue will result in a 12 per cent increase in the SNPV while a 10 per cent increase in material costs will result in about 0.4 per cent decrease in SNPV. If gross revenue were to decrease by 10 per cent and material costs increased by 10 per cent, the SNPV will decrease by 12 per cent (Table 6.6).

TABLE 6.4

CROP: KAVA TONGA AREA UNIT: Hectare

S E N S I T I V I T Y   A N A L Y S I S

Sensitivity Analysis on Discount Rates

SNPV = 3632.75 at a Discount Rate of 8.00

SNPV = 2334.61 at a Discount Rate of 16.00

SNPV = 1469.62 at a Discount Rate of 24.00

SNPV = 881.05 at a Discount Rate of 32.00

Sensitivity Analysis of Costs and Returns

SNPV in T$ at 6.00 percent per annum

Horizontal axis = % change in MATERIAL COST
Vertical axis = % change in GROSS REVENUE

20.0 %	10.0 %	0.0 %	-10.0 %	-20.0 %	
5267.88	5285.68	5303.49	5321.29	5339.09	20.0%
4642.49	4660.30	4678.10	4695.90	4713.70	10.0%
4017.10	4034.91	4052.71	4070.51	4088.31	0.0%
3391.71	3409.52	3427.32	3445.12	3462.93	-10.0%
2766.33	2784.13	2801.93	2819.73	2837.54	-20.0%

From the above discussion, we note that banana production is very sensitive to changing prices and costs as compared to the other crops. This is due to the high input costs of fertilizer and pesticides and the low product price. From this, we can conclude that the banana intercropping

TABLE 6.5

CROP: TONGA OLD COCONUTS 1 AREA UNIT: Hectare

S E N S I T I V I T Y   A N A L Y S I S

Sensitivity Analysis on Discount Rates

SNPV = -441.01 at a Discount Rate of 8.00

SNPV = -380.77 at a Discount Rate of 16.00

SNPV = -339.85 at a Discount Rate of 24.00

SNPV = -310.95 at a Discount Rate of 32.00

Sensitivity Analysis of Costs and Returns

SNPV in TS at 6.00 percent per annum

Horizontal axis = % change in MATERIAL COST
Vertical axis = % change in GROSS REVENUE

20.0 %	10.0 %	0.0 %	-10.0 %	-20.0 %	
-234.72	-179.01	-123.29	-67.58	-11.86	20.0%
-403.20	-347.49	-291.77	-236.06	-180.34	10.0%
-571.68	-515.97	-460.25	-404.54	-348.82	0.0%
-740.16	-684.45	-628.73	-573.02	-517.30	-10.0%
-908.64	-852.93	-797.21	-741.50	-685.78	-20.0%

model poses higher risk to the farmer as compared to kava or vanilla intercropping. The low sensitivity of both the kava and vanilla crops to the changing material costs reflects the high labour requirement in the cost of production as discussed in Chapter 4.

TABLE 6.6

OP: TONGA VANILLA AREA UNIT: Hectare

S E N S I T I V I T Y   A N A L Y S I S

Sensitivity Analysis on Discount Rates

NPV = 36864.40 at a Discount Rate of 8.00
NPV = 20084.58 at a Discount Rate of 16.00
NPV = 11530.77 at a Discount Rate of 24.00
NPV = 6854.50 at a Discount Rate of 32.00

Sensitivity Analysis of Costs and Returns

SNPV in T$ at 6.00 percent per annum

Horizontal axis = % change in MATERIAL COST
Vertical axis = % change in GROSS REVENUE

20.0 %	10.0 %	0.0 %	-10.0 %	-20.0 %	
53317.92	53512.26	53706.60	53900.95	54095.29	20.0%
48145.25	48339.59	48533.93	48728.27	48922.61	10.0%
42972.58	43166.92	43361.26	43555.60	43749.94	0.0%
37799.90	37994.24	38188.59	38382.93	38577.27	-10.0%
32627.23	32821.57	33015.91	33210.25	33404.59	-20.0%

6.2 Comparison of Different Coconut and Intercrop Density

There have been some discussion in the literature reviewed in Chapter 2 about potentials for intercropping during the life span of the coconut stand. It was concluded that under a normal spacing of 7.5m x 7.5m square, very limited or no intercropping can be done between year 8-25. The factor which limits intercropping is the light availability for the intercrops. The models considered in this section will investigate the economic consequences of reducing the coconut density in order to allow continuous intercropping. Also the density of the intercrop is increased for the comparison of economic returns. The kava intercrop is planted under young coconuts aged between 1-12 years. The unit area for the analysis is one hectare and the time period is 12 years. This analysis is assumed to be representative of any intercropping model as all intercrops have higher returns than the coconut sole crop over the same period.

The assumptions about time of planting and gross area utilized by each crop is summarised in Table 6.7. For Tonga Intercropping 2C, the

TABLE 6.7

TIME OF PLANTING AND AREA OCCUPIED BY EACH CROP

Intercropping Model	Crops Grown	Percentage of the Land Utilized By the Crop	Years in Which the Crop Occupies the Land. Year to Year	
Tonga Intercropping 2C	Young Coconut	25	1	12
	Kava	60	1	5
	Kava	60	7	11
Tonga Intercropping 2D	Young Coconut	13	1	12
	Kava	60	1	5
	Kava	60	7	11
Tonga Intercropping 2E	Young Coconut	13	1	12
	Kava	70	1	5
	Kava	65	7	11

coconuts are planted at a density of 123 palms per hectare and the rest of the area is occupied by the kava crop. For Tonga Intercropping 2D, the density of the coconuts is reduced to 62 palms per hectare while the density of the kava intercrop remains the same. For Tonga Intercropping 2E, coconuts are planted at a density of 62 palms per hectare and the density of the kava intercrop is increased.

The costs and returns for the different intercropping models are summarised in Appendix G, Table G.4 - Table G.6. For comparative purposes these tables are summarised and presented in Table 6.8.

TABLE 6.8

RETURN, LABOUR REQUIREMENT AND LOANS FOR
MODELS WITH DIFFERENT DENSITIES OF COCONUTS AND INTERCROP

	Tonga Intercropping 2C	Tonga Intercropping 2D	Tonga Intercropping 2E
SNPV (T$)	8425.67	7887.10	8907.63
SNPV per Labour Day (T$)	5.85	5.64	5.78
Amortized Value per Year (T$)	1004.99	940.75	1062.48
Average Annual Labour Requirement (mandays)	120	116	129
Loans Received (T$)	600	600	600
Grace Period (years)	1	1	1
Repayment Period (years)	4	4	4

From Table 6.8 we note that there is very little difference between the return to labour for the three models. However, in terms of the amortized value, Tonga Intercropping 2E shows that the loss in revenue due to the decreasing of coconut density is offset by increase in revenue due to increasing the density of the intercrop. The difference in labour employment for the three models, ranges from 116 to 129 mandays per hectare per year. In comparing the three models, it seems that the modification reported in Tonga Intercropping 2E gives the best return. Therefore if the coconut density is reduced so as to allow intercropping throughout the life of the coconut, the farmer will get better return by increasing the density of the intercrop. However, as coconut products are important to the economy of Tonga, a form of relay planting could be adopted so that eventually a density of 123 palms per hectare is achieved. This means that half of the coconuts, that is, 62 palms, could be planted first at a spacing of 9m x 18m and the other half planted about 5 years later bringing the final spacing to 9m x 9m. The loss of revenue from the delayed planting of coconuts could be offset by a gain in revenue from increasing the density of the intercrop. This modification, it is assumed, will reduce the light constraint on intercropping. Therefore, this will enable continuous intercropping throughout the coconut life.

6.3 Comparison Between Different Times of Planting of Kava and Banana Intercrops

For this analysis, the intercrops, kava and banana, are grown under coconuts which are 37-48 years old. The period of analysis is 12 years, each year contains 4 seasons. The unit area for the analysis is one hectare. Both the intercrops considered in this section are cash crops. The assumptions about the time of planting and the gross area occupied by individual crops are presented in Table 6.9.

The comparison between the three models is based on what crop to grow first and the growing of a combination of the two intercrops. For all the models, the main crop is coconut aged between 37-48 years old, the intercrops are kava and banana. In all the models, the coconuts are assumed to occupy 25 per cent of the area while the intercrops occupy the rest. For Tonga Intercropping 3, the kava intercrop is planted first from the first to the fifth year of analysis. This was followed by the banana

TABLE 6.9

TIME OF PLANTING AND GROSS AREA OCCUPIED BY EACH CROP

Intercropping Model	Crops Grown	Percentage of the Land Utilized By the Crop	Years in Which the Crop Occupies the Land. Year to Year	
Tonga Intercropping 3	Mature Coconuts	25	1	12
	Kava	60	1	5
	Bananas	60	7	12
Tonga Intercropping 4	Mature Coconuts	25	1	12
	Bananas	60	1	7
	Kava	60	8	12
Tonga Intercropping 5	Mature Coconuts	25	1	12
	Banana	30	1	7
	Kava	30	1	5
	Kava	30	8	12
	Banana	30	6	12

intercrop which occupies the land from the sixth to the twelfth year of the analysis. For Tonga Intercropping 4, the banana intercrop is planted first, followed by the kava intercrop. For Tonga Intercropping 5, it is assumed that the banana intercrop occupies half of the hectare while the kava intercrop occupies the other half. It is assumed that for one half of the hectare, banana is planted as an intercrop under coconuts from the first to the seventh year of the analysis. This is followed by the kava intercrop which occupies that area for the rest of the period of the analysis. For the other half of the hectare, it is assumed that the kava intercrop is planted first. It occupies the land from the first to the fifth year of the analysis. The banana intercrop is planted next, occupying the land for the rest of the period of analysis. For Tonga Intercropping 3 and 4, the farmer is assumed to receive a loan of T$1,400.00 during the establishment phase of the banana crop so as to cover the high costs during the first year of production. For both models, there is a one year grace period with a four year repayment period. For Tonga Intercropping 5, the farmer receives a loan of T$1,000.00 with a one year grace period and a four year repayment period. This loan is proposed to cover the high cost of establishing the banana intercrop. An interest and discount rate of 6 per cent is applied to all the models.

A summary of the costs and returns for the three different models are presented in Appendix G, Table G.7 - Table G.9. Comparative data for these models is presented in Table 6.10.

TABLE 6.10

RETURNS, LABOUR REQUIREMENTS AND LOANS FOR THE DIFFERENT INTERCROPPING MODELS

	Tonga Intercropping 3 (Kava, Banana)	Tonga Intercropping 4 (Banana, Kava)	Tonga Intercropping 5 (Mixture of Kava and Banana)
SNPV (T$)	6707.64	5749.16	6187.18
Amortized Value Per Year (T$)	800.07	685.74	737.99
SNPV Per Labour Day (T$)	3.30	2.83	3.02
Average Annual Labour Requirement (mandays)	169	169	171
Loan Received (T$)	1400	1400	1000
Grace Period (years)	1	1	1
Repayment Period (years)	4	4	4

There is very little difference between the three models with regard to the return to labour as reported by the SNPV per labour day. However, all values are below the minimum basic hired wage rate of T$4.00.

This is due to the low return to labour for banana intercropping as reported in Table 6.2. The amortized values for the three models ranges from T$685.74 to T$800.07. Tonga Intercropping 3 gives a better amortized value than Tonga Intercropping 4. This is due to the effect of the discount rate. For Tonga Intercropping 3, the kava intercrop, with a high SNPV, is grown first. Therefore, it is discounted over a shorter period as compared to Tonga Intercropping 5 where kava is planted in the last period. Thus if we consider the kava intercrop alone, the SNPV for Tonga Intercropping 3 will be higher than that for Tonga Intercropping 4. Tonga Intercropping 5, where a mixture of both kava and banana are grown throughout the period of analysis, gives a higher amortized value than Tonga Intercropping 4 where banana is grown first followed by the kava intercrop. The difference in labour requirements between the three models is 2 mandays.

In comparing the three models, we note that the time of planting and the crop mix are important in their individual contribution to economic returns due to intercropping. The sensitivity analyses for the different crops have been discussed in Section 6.1 of this chapter. Tonga Intercropping 3 has the advantage over the other two models in terms of the SNPV, amortized value and the SNPV per labour day. Tonga Intercropping 5 gives better returns than Tonga Intercropping 4. This implies that intercropping of coconut with kava and banana as a mixture may give a better result than growing one hectare of banana for the first seven years followed by one hectare of kava for the remaining 5 years. It is also noted that crops with low returns such as bananas, are better grown together with other crops, such as kava, which has high returns. Therefore, the farmer could spread the risk of crop failure by growing more than one intercrop. Also, the farmer could improve his return to labour and the amortized value by growing bananas with other crops as compared to intercropping with banana alone

6.4 Comparison Between Different Annual Crop Combinations

The intercropping models considered in this section are based on the traditional crop rotation. All the models adopted banana as the cash crop to be grown from year 6-12 of the period of analysis. Other cash crops could be used but this will not change the relative results. The other crops considered in the models are yams, swamp taro, xanthosoma, capsicum and cassava. The period of analysis is 12 years with each year consisting of 4 seasons. For all the models, the intercrops are planted under coconuts between the age of 37-48 years. The unit area for each model is one hectare. The assumptions about the time of planting and the gross area occupied by each crop is presented in Table 6.11.

For all the models, the planting time for the intercrops is assumed to be the first season. For all the crops except yams, they can be planted at any time of the year. However, planting during the first season is assumed to give the best yield. For yams, the main planting season is the third season. However, yams are also planted in the first season for harvest during the Christmas period. The intercrops are assumed to occupy a total area of one hectare per year. For capsicum, it is assumed that 2 crops are planted per hectare per year. It should be noted that any other coconut age group selected for the analysis will not change the relative results. Because yams are important, both for the family consumption and for fulfilling social obligations, it is included in all the models. Cassava is a crop planted mainly to fulfil subsistence requirements. Capsicum and swamp taro are included as cash crops while xanthosoma can be considered both as a cash as well as a subsistence crop. The size of the market and the product price determines the proportion of swamp taro and xanthosoma production that is sold as cash crop.

TABLE 6.11

TIME OF PLANTING AND GROSS AREA OCCUPIED BY EACH CROP

Intercropping Model	Crops Grown	Percentage of the Land Occupied By the Crop	Years in Which the Crop Occupies the Land. Year	to Year
Tonga Intercropping 6	Mature Coconut	25	1	12
	Yams	60	1	1
	Swamp Taro	70	2	2
	Xanthosoma	70	3	3
	Cassava	70	4	4
	Bananas	60	6	12
Tonga Intercropping 7	Mature Coconuts	25	1	12
	Yams	60	1	1
	Capsicum	70	2	2
	Xanthosoma	70	3	3
	Cassava	70	4	4
	Bananas	70	6	12
Tonga Intercropping 8	Mature Coconuts	25	1	12
	Yams	60	1	1
	Swamp Taro	70	2	2
	Capsicum	70	3	3
	Cassava	70	4	4
	Bananas	60	6	12
Tonga Intercropping 9	Mature Coconuts	25	1	12
	Yams	60	1	1
	Swamp Taro	70	2	2
	Xanthosoma	70	3	3
	Capsicum	70	4	4
	Bananas	60	6	12

For all the models, it is assumed that a loan of T$1,400.00 is available in the 6th year. This loan is to cover the establishment cost of the banana production. The farmer is given a one year grace period and a four year repayment period. A discount and interest rate of 6 per cent is applied to all the models.

For Tonga Intercropping 6, the intercrops occupies one hectare of coconut land per year. Yams are planted in the first year followed by swamp taro in the second year, xanthosoma in the third year, cassava in the fourth year and lastly banana which occupies the land from the sixth to the twelfth year. For Tonga Intercropping 7, capsicum replaces swamp taro, as the annual cash crop in the crop rotation. Capsicum replaces xanthosoma in Tonga Intercropping 6 to form Tonga Intercropping 8. Therefore, Tonga Intercropping 8 contains two annual cash crops. That is, capsicum and swamp taro. Capsicum replaces cassava in Tonga Intercropping 6 to form Tonga Intercropping 9. Therefore, Tonga Intercropping 9 contains three potential annual cash crops. These include capsicum, swamp taro and xanthosoma. For all the models, the fifth year of the period of analysis is left fallow. The different models reflect varying degrees of annual cash cropping.

The costs and returns for the different intercropping models are presented in Appendix G, Table G.10 - Table G.13. A summary of the results are presented in Table 6.12.

In terms of the return to labour, there is hardly any difference between the SNPV per labour day for the different models. However, the SNPV per labour day for all the models are lower than the basic minimum hired wage rate of T$4.00. This is due to the low return to labour for banana intercropping as discussed in Section 6.1 of this chapter. If we substitute bananas with another perennial cash crop, such as kava or vanilla, the return to labour for the models will be much higher than the basic minimum hired wage rate. There is very little difference between the annual return, as reported by the amortized value, for the different intercropping models. The amortized values ranges from T$731.23 to T$793.46. The annual labour requirement in mandays shows uniformity between the models. There is a difference of 6 mandays between the lowest and the

TABLE 6.12

RETURNS, LABOUR REQUIREMENTS, AND LOANS FOR DIFFERENT ANNUAL CROP MIXES

	Tonga Inter-cropping 6	Tonga Inter-cropping 7	Tonga Inter-cropping 8	Tonga Inter-cropping 9
SNPV (T$)	6247.63	6652.26	6293.09	6130.55
Amortized Value Per Year	745.20	793.46	750.62	731.23
SNPV Per Labour Day	3.22	3.32	3.13	3.08
Average Annual Labour Requirement (mandays)	162	167	168	166
Loans Received	1400	1400	1400	1400
Grace Period (years)	1	1	1	1
Repayment Period (years)	4	4	4	4

highest requirement. Tonga Intercropping 7 seems to give the best economic result in terms of the return to labour, SNPV and the amortized value per year.

There seems to be very little difference in economic returns from different combinations of crops considered in the above models. However, there are other factors that should be considered by the farmers when choosing their intercrops under coconuts. These factors include the availability of markets, crop preference, level of management and skills required for each crop, susceptibility to the weather, level of inputs and the changing product prices. Therefore, it is important to look at the sensitivity of the model to changes in material costs and gross revenue. The sensitivity of the SNPV of individual crops to changing costs and returns apart from other criteria, can be used by individual farmers as a basis for selecting crops to be grown.

The sensitivity of each crop to changing prices and costs can be explained by referring to the sensitivity analysis table for individual crops. The sensitivity analysis for the banana crop has been discussed previously in this chapter.

For yams (Table 6.13), a 10 per cent increase in material cost will result in a 7 per cent decrease in the SNPV while a 10 per cent decrease

TABLE 6.13

CROP: TONGA YAMS

AREA UNIT: Hectare

S E N S I T I V I T Y   A N A L Y S I S

Sensitivity Analysis on Discount Rates

SNPV = 1798.15 at a Discount Rate of 8.00
SNPV = 1620.71 at a Discount Rate of 16.00
SNPV = 1467.12 at a Discount Rate of 24.00
SNPV = 1332.98 at a Discount Rate of 32.00

Sensitivity Analysis of Costs and Returns
SNPV in T$ at 6.00 percent per annum
Horizontal axis = % change in MATERIAL COST
Vertical axis = % change in GROSS REVENUE

20.0 %	10.0 %	0.0 %	-10.0 %	-20.0 %	
2371.44	2492.60	2613.75	2734.90	2856.05	20.0%
1988.01	2109.16	2230.31	2351.46	2472.62	10.0%
1604.58	1725.73	1846.88	1968.03	2089.18	0.0%
1221.14	1342.29	1463.44	1584.60	1705.75	-10.0%
837.71	958.86	1080.01	1201.16	1322.31	-20.0%

in gross revenue will result in a 21 per cent decrease in SNPV. A 10 per cent increase in material costs and 10 per cent decrease in gross revenue will result in about 27 per cent decrease in the SNPV. We note here that yams are more sensitive to changes in gross revenue than to changes in material costs. This is important in the sense that, because yam production uses a high percentage of labour, the increases in material costs do not affect the SNPV very much. However, improved product price will increase the SNPV to a larger extent.

For swamp taro (Table 6.14), a 10 per cent decrease in gross

TABLE 6.14

ROP: TONGA SWAMP TARO AREA UNIT: Hectare

S E N S I T I V I T Y A N A L Y S I S

Sensitivity Analysis on Discount Rates

SNPV = 334.27 at a Discount Rate of 8.00
SNPV = 289.65 at a Discount Rate of 16.00
SNPV = 251.19 at a Discount Rate of 24.00
SNPV = 217.75 at a Discount Rate of 32.00

Sensitivity Analysis of Costs and Returns

SNPV in T$ at 6.00 percent per annum

Horizontal axis = % change in MATERIAL COST
Vertical axis = % change in GROSS REVENUE

20.0 %	10.0 %	0.0 %	-10.0 %	-20.0 %	
488.25	556.96	625.67	694.38	763.09	20.0%
348.70	417.40	486.11	554.82	623.53	10.0%
209.14	277.85	346.56	415.27	483.97	0.0%
69.58	138.29	207.00	275.71	344.42	-10.0%
-69.97	-1.27	67.44	136.15	204.86	-20.0%

revenue will result in a 40 per cent decrease in the SNPV while a 10 per cent increase in material cost will result in a 20 per cent decrease in the SNPV. If the gross revenue decreases by 10 per cent and the material costs increases by 10 per cent, the SNPV will decrease by 60 per cent. The SNPV is more sensitive to changes in gross revenue as compared to material costs. The product price is a very important determinant of the SNPV. Therefore, a slight increase in price or yield while other things remain constant, will result in a much higher increase in SNPV. Therefore, the development of export markets with improved prices is essential so as to give better returns to swamp taro production. For the gross revenue, the labour requirement for production is likely to remain constant. The yield could be increased by employing new technologies. The item most susceptible to change is the product price.

For xanthosoma (Table 6.15), a 10 per cent increase in material costs will result in a 4 per cent decrease in the SNPV while a 10 per cent decrease in gross revenue will result in a 22 per cent decrease in the SNPV. If the gross revenue were to decrease by 10 per cent and material costs increased by 10 per cent, the SNPV will decrease by about 22 per cent. The low sensitivity of the SNPV to increases or decreases in material costs is due to the low percentage of material costs in the total cost of production (refer to Chapter 4). The SNPV is more sensitive to changes in gross revenue as compared to changes in material costs. Therefore, an increase in either product price or yield will result in a higher increase in the value of the SNPV.

For capsicum (Table 6.16), a 10 per cent increase in material costs will result in a 18 per cent decrease in the SNPV while a 10 per cent decrease in gross revenue will result in 37 per cent decrease in the SNPV. If the gross revenue decreases by 10 per cent and the material costs increase

TABLE 6.15

CROP: TALO FUTUNA(XANTHOSOMA) AREA UNIT: Hectare

S E N S I T I V I T Y   A N A L Y S I S

Sensitivity Analysis on Discount Rates

SNPV = 713.29 at a Discount Rate of 8.00
SNPV = 648.42 at a Discount Rate of 16.00
SNPV = 592.22 at a Discount Rate of 24.00
SNPV = 543.09 at a Discount Rate of 32.00

Sensitivity Analysis of Costs and Returns

SNPV in T$ at 6.00 percent per annum

Horizontal axis = % change in MATERIAL COST
Vertical axis = % change in GROSS REVENUE

20.0 %	10.0 %	0.0 %	-10.0 %	-20.0 %	
944.19	973.00	1001.81	1030.62	1059.43	20.0%
808.84	837.64	866.45	895.26	924.07	10.0%
673.48	702.29	731.09	759.90	788.71	0.0%
538.12	566.93	595.73	624.54	653.35	-10.0%
402.76	431.57	460.38	489.18	517.99	-20.0%

by 10 per cent, the SNPV will decrease by about 55 per cent. From this analysis it is clear that the SNPV is very sensitive to changes in both the material costs and gross revenue. The high sensitivity to changes in material costs is attributed to the high percentage of the material costs

TABLE 6.16

ROP: TONGA CAPSICUM AREA UNIT: Hectare

SENSITIVITY ANALYSIS

Sensitivity Analysis on Discount Rates

SNPV = 707.38 at a Discount Rate of 8.00

SNPV = 653.97 at a Discount Rate of 16.00

SNPV = 607.32 at a Discount Rate of 24.00

SNPV = 566.21 at a Discount Rate of 32.00

Sensitivity Analysis of Costs and Returns

SNPV in T$ at 6.00 percent per annum

Horizontal axis = % change in MATERIAL COST
Vertical axis = % change in GROSS REVENUE

20.0 %	10.0 %	0.0 %	-10.0 %	-20.0 %	
987.84	1119.34	1250.84	1382.35	1513.85	20.0%
723.40	854.91	986.41	1117.91	1249.41	10.0%
458.97	590.47	721.97	853.47	984.98	0.0%
194.53	326.03	457.53	589.04	720.54	-10.0%
-69.91	61.60	193.10	324.60	456.10	-20.0%

in the total cost of production. The profitability of the capsicum production is highly dependent on the product price and the yield per hectare. The product price plays an important role with regards to the level of economic returns. Hence this is a high risk crop not only in terms of economic returns but also because it requires a high level of management ability.

For cassava (Table 6.17), a 10 per cent increase in material costs will result in about 0.4 per cent decrease in the SNPV while a 10 per cent decrease in gross revenue will result in a 16 per cent decrease in the SNPV. If the gross revenue decreases by 10 per cent and the material costs increases by 10 per cent, the SNPV will decrease by about 17 per cent. For

TABLE 6.17

ROP: TONGA CASSAVA AREA UNIT: Hectare

S E N S I T I V I T Y A N A L Y S I S

Sensitivity Analysis on Discount Rates

SNPV = 871.97 at a Discount Rate of 8.00
SNPV = 795.37 at a Discount Rate of 16.00
SNPV = 728.96 at a Discount Rate of 24.00
SNPV = 670.86 at a Discount Rate of 32.00

Sensitivity Analysis of Costs and Returns
SNPV in T$ at 6.00 percent per annum
Horizontal axis = % change in MATERIAL COST
Vertical axis = % change in GROSS REVENUE

20.0 %	10.0 %	0.0 %	-10.0 %	-20.0 %	
1156.51	1168.53	1180.55	1192.56	1204.58	20.0%
1012.73	1024.75	1036.76	1048.78	1060.80	10.0%
868.95	880.96	892.98	905.00	917.01	0.0%
725.16	737.18	749.20	761.21	773.23	-10.0%
581.38	593.40	605.41	617.43	629.45	-20.0%

cassava, the SNPV is not sensitive to changes in the material costs. This is due to the very low level of material costs in the total cost of production. The main cost in cassava production is the labour cost. However, the SNPV is almost solely determined by the product price and the yield. Cassava is a very low risk crop as compared to capsicum.

In summary, cassava, xanthosoma and yams have very low sensitivity to material costs. The SNPV is more sensitive to changes in gross revenue. This means that to improve the SNPV for these crops, either the price or the yield or both should be improved. Swamp taro and capsicum are sensitive to changes in both the material costs and the gross revenue. However, both crops are more sensitive to changes in the gross revenue. High sensitivity to material costs are a reflection of the high percentage of the material costs in the total cost of production. The high sensitivity to changes in gross revenue means that a slight change in either the yield or the product price will affect the SNPV to a marked extent.

6.5 Tax Allotment Modelling

In this section, six sets of intercropping models are considered. The unit area used as a basis for each model is one hectare. For the analysis of the tax allotment (3.34 hectares), one hectare is devoted to perennial cash intercrops such as kava, banana and vanilla. The rest is devoted to a mixture of subsistence crops and annual cash crops plus fallow periods. The annual crops include yams, swamp taro, xanthosoma, capsicum and cassava. For the annual crops, capsicum and swamp taro are assumed to be grown as cash crops. The modelling adopts the traditional crop rotation with a crop of yams, swamp taro and xanthosoma planted every year. One set of models adopted cassava as the fourth annual crop and the other set adopted capsicum.

The analyses, except for vanilla intercropping, uses a time period of 5 years with 4 seasons per year. For the mixture of annual crops, yams occupy 24 per cent of the land per crop while the other crops each occupy 28 per cent of the land per crop. Kava, banana and vanilla are assumed to occupy one hectare of coconut land. It is assumed that all the crops are planted during the first season, thereby highlighting the seasonal and annual labour requirements per tax allotment. However, in practice, the planting of the different crops may be spread throughout the year, thus reflecting a different pattern of labour requirement.

The intercropping models considered for modelling of a tax allotment are presented in Table 6.18.

For the tax allotment models, it is assumed that the labour availability per season is 96, 104, 104 and 96 mandays, respectively. For all the intercropping models, except Vava'u Intercropping 1, the intercrops are assumed to be under coconuts which are 61-65 years old. For Vava'u Intercropping 1 the vanilla intercrop is assumed to be planted under young coconuts which are 1-15 years old. The modelling of the tax allotment was done on the basis of hectare by hectare with a total of three hectares per tax allotment model. This assumes that the rest of the tax allotment is left fallow. For the tax allotment modelling the available labour is applied first to the models containing the subsistence and annual cash crops. Any labour which is left over is then applied to the model containing the perennial cash crop. Therefore, excess labour requirement will be hired from outside the family unit.

The different model combinations which forms the tax allotment models are as follows:

Tax Allotment A:

Tonga Intercropping 10, Tonga Intercropping 11 and Tonga Intercropping 12

TABLE 6.18

INTERCROPPING MODELS FOR TAX ALLOTMENT ANALYSIS

Year	Tonga Intercropping 10		Tonga Intercropping 11		Tonga Intercropping 12
1	Yams	Swamp Taro	Xanthosoma	Cassava	Kava
2	Swamp Taro	Xanthosoma	Cassava	Yams	Kava
3	Xanthosoma	Yams	Cassava	Swamp Taro	Kava
4	Cassava	Swamp Taro	Yams	Xanthosoma	Kava
5	Cassava	Xanthosoma	Swamp Taro	Yams	Kava

Year	Tonga Intercropping 13	Tonga Intercropping 14		Tonga Intercropping 15	
1	Banana	Yams	Swamp Taro	Xanthosoma	Capsicum
2		Swamp Taro	Capsicum	Yams	Xanthosoma
3		Capsicum	Yams	Swamp Taro	Xanthosoma
4		Xanthosoma	Swamp Taro	Capsicum	Yams
5	Banana	Yams	Capsicum	Xanthosoma	Swamp Taro

Year		Tonga Intercropping 16	Tonga Intercropping 17
1		Kava	Banana
2			
3			
4			
5		Kava	Banana

Year	Vava'u Intercropping 1
1	Vanilla
2	
⋮	
15	Vanilla

Tax Allotment B:

Tonga Intercropping 10, Tonga Intercropping 11 and Tonga Intercropping 13

Tax Allotment C:

Tonga Intercropping 10, Tonga Intercropping 11 and Vava'u Intercropping 1

Tax Allotment D:

Tonga Intercropping 14, Tonga Intercropping 15 and

Tonga Intercropping 16

Tax Allotment E:

Tonga Intercropping 14, Tonga Intercropping 15 and

Tonga Intercropping 17

Tax Allotment F:

Tonga Intercropping 14, Tonga Intercropping 15 and

Vava'u Intercropping 1.

For Tax Allotment A, the annual crops included in the model include yams, swamp taro, xanthosoma and cassava. These are grown on a four year rotation. The perennial cash crop considered is kava. For Tax Allotment B, the annual crop combination is the same as that for Tax Allotment A. However, kava is substituted by the banana intercrop. For Tax Allotment C, the annual crop combination is the same as that for Tax Allotment A but the vanilla perennial cash crop replaces the kava intercrop. Capsicum replaces cassava in Tax Allotment A to form Tax Allotment D. The banana intercrop replaces the kava intercrop in Tax Allotment D to form Tax Allotment E. Vanilla replaces kava in Tax Allotment D to form Tax Allotment F.

The returns and labour requirements for the individual models are presented in Table 6.19.

In terms of the return to labour, the SNPV per labour day for the banana intercropping models (Tonga Intercropping 13 and 17) are much lower than the basic minimum wage rate of T$4.00. The other models reported a return to labour higher than the basic minimum wage rate. For the perennial cash crops, the individual models show that intercropping with vanilla (Vava'u Intercropping 1) is the most profitable followed by kava (Tonga Intercropping 12 and 15) while banana intercropping (Tonga Intercropping 13

TABLE 6.19

RETURNS AND LABOUR REQUIREMENT FOR THE DIFFERENT INTERCROPPING MODELS

Model	SNPV	SNPV Per Labour Day	Amortized Value Per Year	Average Annual Labour Requirement (mandays)
Tonga Intercropping 10	3864.79	6.54	917.49	118
Tonga Intercropping 11	4462.35	6.94	1059.35	129
Tonga Intercropping 12	4594.16	6.56	1090.64	140
Tonga Intercropping 13	1782.83	1.86	423.24	191
Tonga Intercropping 14	4182.87	5.94	993.00	141
Tonga Intercropping 15	3885.52	6.20	922.41	125
Tonga Intercropping 16	4594.80	6.56	1090.79	140
Tonga Intercropping 17	1813.92	1.90	430.62	191
Vava'u Intercropping 1	45272.78	13.56	4661.41	223

and 17) is the least profitable. For the modelling of the annual crop combinations (Tonga Intercropping 10, 11, 14, 15) the amortized values ranges from T$917.49 to T$1,059.35 while the SNPV per labour day for all these models are about the same.

For modelling of the tax allotment, it was also assumed that the family wage rate are T$2.80, T$3.20, T$3.20 and T$2.80 for the four seasons respectively. The tax allotment models are composed of linear combinations of the results of individual models considered. Comparative data of the returns and labour requirements for the different tax allotment models are presented in Table 6.20.

In terms of the SNPV per labour day, all the tax allotment models reported a return to labour which is higher than the basic minimum wage rate. However, it should be noted that the values for Model C and Model F are much higher. For the amortized values, Model C and Model F reported the highest values, followed by Model A and Model D. The least values are reported by Model B and Model E.

TABLE 6.20

AVERAGE RETURN AND LABOUR REQUIREMENT
PER TAX ALLOTMENT

Tax Allotment Models	Amortized Value Per Year (T$)	SNPV Per Labour Day (T$)	Average Annual Labour Requirement
A	3067.48	6.68	387
B	2400.08	5.11	438
C	6638.25	9.01	470
D	3006.20	6.23	406
E	2346.03	4.68	457
F	6576.82	8.57	489

Therefore, in terms of economic returns to intercropping, the models which adopt vanilla as the perennial cash crop give the highest return. This is followed by the models adopting kava as the perennial cash crop. The models adopting banana as the perennial cash crop give the lowest economic return.

There is very little difference in economic returns when we compare the results with the inclusion of either capsicum (Model D) or cassava (Model A) in the tax allotment models. However, the farmer who wants to grow more cash crops and who has the ability and management skill, may choose Model D although the return is less than Model A.

In terms of labour requirements there is a wide range between the models. The range is from 387-489 mandays per year. This is comparable with the annual family labour availability of 400 mandays. It should be noted that the tax allotment models (C and F), which include vanilla as the perennial cash crop, require the most labour followed by banana (B and E) and then kava (A and D). The analysis also shows the seasonal labour requirements, highlighting the need for hired labour. As an example the seasonal labour requirement for Tax Allotment A is summarised in Table 6.21. It should be noted that under the assumptions made for the individual crops

TABLE 6.21

LABOUR REQUIREMENT FOR TAX ALLOTMENT A

Year	Season	Total Labour Required	Family Labour	Hired Labour	Excess Family Labour
1	1	102	96	6	-
	2	123	104	19	-
	3	77	104	-	27
	4	131	96	35	-
2	1	132	96	36	-
	2	71	104	-	33
	3	63	104	-	41
	4	118	96	22	-
3	1	114	96	18	-
	2	93	104	-	11
	3	65	104	-	39
	4	100	96	4	-
4	1	134	96	38	-
	2	65	104	-	39
	3	83	104	-	21
	4	112	96	16	-
5	1	109	96	13	-
	2	122	104	18	-
	3	31	104	-	73
	4	90	96	-	6

Note: All labour is reported in mandays.

and for modelling, there are some seasons in which there is an excess of labour while other seasons require hired labour. In this case the time of planting is important with regard to the labour requirement. Normally, excess labour requirements fall during the third season where most of the yam planting is done and during the second season where most of the yam harvesting is done. However, the hired labour requirement will depend on the type of crops grown and the time of planting for each crop considered in the tax allotment.

Therefore, the farmer who wishes to fulfil his subsistence as well as cash requirements from his tax allotment will be better off if he grows vanilla and kava in that order as his perennial cash crops. Under the assumptions made for modelling, it is noted that banana intercropping is unprofitable.

CHAPTER 7

SUMMARY AND CONCLUSIONS

The agricultural sector in Tonga forms the basis for economic development. The sector is the highest foreign exchange earner for the Kingdom. The importance of the agricultural sector is clearly stated in the Tonga Fourth Five Year Development Plan, 1980-1985. The foundation for the economic development of the agricultural sector is the smallholder farmers. Therefore, the resources for development of the economy are largely governed by the size of the land holdings (tax allotment), the size of the farm family labour, the extended family labour and how these are organized for production purposes. In spite of the importance of the smallholder sector, there is little interest shown in the economic analysis of the family farm unit. Very little formal intercropping has been undertaken and hence there is scope for investigation in this area. The intercropping systems should be analysed critically for the different island groups of Tonga. This analysis should be based on field trials.

The products of the coconut tree are very important to the Tongan people as well as the economy. While coconut provides a range of important subsistence needs, its major role is to earn foreign exchange. In this sense, coconut is also a cash crop for the farm family. The importance of the coconut industry to the nation is shown by the commitment made by the government on resource allocation and area replanted through the Coconut Replanting Scheme Project. Although coconut is very important to the national economy, the analysis, as reported in Chapter 4, shows that the return to labour for a sole coconut stand is very low when compared to other crops. The low return to labour could contribute to the poor maintenance of sole coconut stands. The coconut income stream, as reported in Chapter 4, is very low as compared to the other crops. However, with intercropping, as reported in Chapter 5, the net revenue per year will be greatly increased through the saving of labour required for weeding of a sole coconut stand. Therefore, one of the advantages of intercropping is this beneficial interactive effect with regards to weeding. The increase in net revenue of coconuts through saving of labour in weeding was estimated at about T$80.00 per hectare per year. Thus intercropping makes coconut production more profitable.

An evaluation of coconut intercropping systems was made by comparing the returns and labour requirements for different intercropping models. Due to the importance of coconut in the farming systems and the national economy all models adopted coconut as the main crop. The profitability of different intercrops grown under coconuts were compared in terms of the model's SNPV, amortized value and the return to labour.

The review of potential intercropping systems was based on various studies of the multistoreyed cropping pattern developed at the Central Plantation Crops Research Institute at Kasaragod in South India. The models adopted for the analysis are static models, considering certain time periods. This was relevant to the study because the objective was to compare the profitability and labour requirements of different intercrops or crop mixes under coconuts.

The limitation of the present system of coconut planting is the limited or no potential for intercropping during the intermediate period, 8-25 years age. Therefore, the potential earning from the coconut land is much lower. Thus consideration was given to the possibility of reducing coconut density so as to increase the intercropping potential during the intermediate period. There was also a need for the adoption and development of shade tolerant crops under coconuts. These crops should have a potential market, are non-perishable and highly valued. An example is the vanilla intercrop.

The models considered in the analysis compare economic returns and labour requirements. This can be easily done for perennial cash crops for they are grown solely for cash. However, for the annual crops, which have the dual role of being a subsistence crop as well as cash crop for the export market, the problem becomes complex. The potential of a crop for cash marketing is dependent on the availability of the market as well as the product price level. Therefore, for the root crops, the proportion of the output used for family consumption is important when determining the actual net cash income of the farm family. In this case the model may show a high return in terms of the SNPV and amortized value. However, in actual fact the farm family's net cash income will be less due to a high percentage of the production being consumed by the farm family or used to fulfil social obligations. An example of this is yam production where a large proportion of the output is consumed by the farm family. In contrast, capsicum production may be grown solely as a cash crop. Therefore, capsicum will give a higher net cash return to the farmer. Because of this, the degree of importance of individual models to individual farmers will vary.

The data used for the analysis of the cash flows and later for modelling were assembled from various sources. The coconut yield data was adopted from plantation yields in the Solomon Islands. This yield could have been higher than smallholder yield due to better management practices. For the smallholder farmer in Tonga, the copra price could be important in determining the level of copra produced. Hence the coconut yield could be high but the proportion converted to copra may be low. Further studies could clarify the position. An important need is a field estimate of coconut yield stream for Tonga stating estimated yield per year for use in future intercropping analysis. In this study some of the data were adopted from intercropping trials at Research Stations of the M.A.F.F. Hence quantities of inputs and outputs relating to each crop could be higher than that experienced by an individual farmer. Because of the nature of the present data set and the continuous requirement for future economic analysis, the design of future experiments to investigate coconut intercropping potentials should include the constraints in production experienced by the smallholders. Such experiments should have a long term basis and include inputs, outputs and level of management practices. Long term experiments on crop rotations should be done also.

The MULBUD technique used in the analysis was very useful for the comparison of the different intercropping models. It provides a quick way of answering many alternative questions faced by the farmer. Also future returns for different crops or models can be summarised quickly thereby helping the operator in his choice of intercrops. The break-even point for any crop can be calculated with ease. This could help the farmer in his decision on what price he should adopt for his product, especially in the domestic market. The sensitivity analysis will also help the farmer in making his decision on what crops he should grow. From modelling, the operator can, under the assumptions made, quickly estimate the annual returns, return to labour and labour requirements.

The MULBUD technique has some limitations, although these limitations did not affect the analysis of the different models considered in this study. Modelling can be done on either a per acre or per hectare basis. So for the modelling of the tax allotment, it has to be done on a hectare by hectare basis. Therefore, the amount of labour available for each succeeding model has to be calculated after the preceding model for the first hectare has been run through the computor. Not only this but the returns and labour requirements for the tax allotment have to be calculated by hand using an average for the return to labour and a linear combination (addition) for the other factors. The technique reported gives amortized value and labour requirement on an annual basis. Thus, if the crop occupies the land for 16 months the result will be as if the crop occupied the land for 24 months. Therefore, the actual annual labour requirement reported would be less than it really is. To avoid this complication, all the annual crops were assumed to be planted in the first season. This limitation applied only to the annual crops. For the perennial crops there were no such problems. The fixed costs for the individual crops could be included in the model as variable costs. Therefore fixed costs which applied to particular crops were included. Others such as basic tools, which have long replacement periods and are used by almost all the crops were not included. It was felt that the cost per year would not significantly alter the result.

From the results, it was concluded that vanilla is the most profitable perennial intercrop to be grown under coconuts. This was followed by kava and lastly bananas. In terms of labour requirements, vanilla intercropping require the most labour, followed by banana then kava. Vanilla has very little material inputs as well as kava, therefore, they are not very sensitive to changes in material costs. Both vanilla and kava have a highly beneficial impact on the economic results of other intercropping models of the tax allotment while banana intercropping has the reverse effect. This is clearly shown by the Tax Allotment Models A-F. However, it is clear that if everyone grew vanilla, the returns will diminish due to overproduction. This is an area where government policy is much needed for future development strategy.

Banana production is unprofitable without the subsidy under the assumptions made for modelling. However, if the yield per hectare of high quality bananas is increased, or the product price increases, the economic return will improve. This is shown clearly by the sensitivity analysis where a 10 per cent increase in gross revenue will result in about 80 per cent increase in the SNPV. Since Tonga experiences a hurricane hazard, the banana producer faces a great risk if the subsidy is removed. This is due to the high material costs in the total cost of production of the banana intercrop which averages at about T$1,400.00 for the first year. If a hurricane or strong winds damaged the banana plantations before an yield stream began the farmers will lose a lot in terms of material inputs. This will also affect their future decisions about growing bananas.

The growing of kava should be encouraged. This intercrop is not only non-perishable but it has a high value in the domestic market. Kava, as mentioned earlier, has very high returns. There is a sizeable domestic market and also a potential export market to nearby Pacific islands.

The returns for individual annual crops are comparable except for swamp taro. This was due to swamp taro being considered only as an export crop. The cost of producing for export is very high. The returns for the models, consisting of different annual intercrop mixes, are also comparable. However, the degree of cash earnings depends on the availability of the market, the product price and the percentage of crop yield that is being consumed by the farm family. The farmer can choose the type of model to adopt depending on his objectives. These could be either to grow more cash crop, more subsistence crop or a balance between the two keeping in mind his cash, labour and land constraints.

The modelling also highlighted the seasonal labour requirements and the returns to labour for particular models under different assumptions. The modelling technique also indicated the amount of material costs required for individual crops. These can help the farmer in his choice of crop mixes to be grown on his tax allotment.

The possibility of reducing the coconut density to facilitate continuous intercropping was also considered. It was considered that due to the land constraint, the smallholder cannot afford to lose about 17 years of potential intercropping based on the present system of coconut plantings. Hence coconut density could be reduced at first to allow continuous intercropping. Although the net return per hectare was initially low it could be raised by increasing the density of the intercrop. The density of the coconut could be increased afterwards. This hypothesis requires further empirical tests. It must be stressed that the results obtained in this study are only as good as the data and the assumptions made.

Finally, it is concluded that systematic intercropping under coconuts is a potentially useful farming system for Tonga. Not only is it important in its contribution to the farm family's subsistence and social obligations but it also has the potential for major contributions to the total economic development of Tonga.

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APPENDIX A

Supplementary discussion to the cash flow analysis chapter.

A1.1 The Coconut Industry in Tonga

The coconut industry contributes substantially to the foreign exchange earnings of the Kingdom. Apart from this, about 25 per cent of the coconut production (nuts) is utilized domestically for cooking, drinking, eating and feeding to livestock (Table A.1). Other component parts of the coconut tree have particular uses to the farm family. These include: (a) roof thatching (leaves); (b) coconut timber for construction (stem); (c) fishing nets (roots); (d) handicrafts (leaf spines, leaf bud cover); (e) firewood (stem, calyx, leaf stem coconut husk, coconut shell); (f) cups

TABLE A.1

POTENTIAL COPRA PRODUCTION (tonnes) 1974-1979

	1974	1975	1976	1977	1978	1979
Copra Purchased	12271	15687	13899	12713	8653	8650
Desiccated Coconut and Copra	1286	1264	1300	1397	934	1082
Whole Nuts Commodities	94	194	99	163	34	31
Whole Nuts Private	133	133	102	147	54	19
Domestic Use (Percentage)	4426 (24.5)	4468 (20.6)	4504 (22.6)	4573 (24.1)	4642 (32.4)	4712 (32.5)
Total Production	18077	21746	19904	18993	14317	14494

Source: Dean (1981).

(coconut shell); (g) strings, ropes and door mats (coconut husk); (h) baskets and mats (leaves); (i) making brooms (leaf spines); and (j) ornamentals (shells).

The coconut palm population for Tongatapu, Vava'u and Ha'apai was estimated by conducting a survey in 1979 (DP IV). A Coconut Age Distribution and Productivity Survey was carried out in 1980. From the above surveys, it was estimated that about 40,600 hectares (57 per cent) of the total land area was under coconuts. The result of the above surveys are presented in Table A.2 and Table A.3. There is a discrepency in the total number of palms between the two tables. This may be due to an error in counting and estimation.

TABLE A.2

COCONUT PALM POPULATION (1980)

Island Group	Tax Allotments and Small Estates Up To 20 Hectares	Large Estates Over 20 Hectares	Total
Tongatapu	2,158,000	212,000	2,370,000
Vava'u	1,252,000	54,000	1,306,000
Ha'apai	947,000	6,100	953,100
'Eua) Nuiatoputapu) Niuafo'ou)	321,000		321,000
			4,950,100

Source: DP IV.

A.1.2 The Coconut Replanting Scheme

During the late 1960s, an expert from the United Nations was

TABLE A.3

RESULTS OF THE AGE DISTRIBUTION AND PRODUCTIVITY SURVEY

Category	Age Distribution Years Until Estimated Ready For Stem Utilization	Number of Palms	Estimated Annual Productivity Based on Nut Count
Senile	0-5	580,000	7
Senescent	6-10	710,000	23
Old Mature	11-15	960,000	31
Mature	16+	1,280,000	27
Young Mature		470,000	9
Immature		960,000	0
Total		4,960,000	

Source: DP IV.

recruited to appraise the coconut situation of the Kingdom. This was based on the likelihood of replacing senile palms, increasing coconut acreage and estimating potential for increasing foreign exchange earnings. The first scheme started in 1965 and extended to 1972. A project leader was recruited under the United Kingdom Technical Assistance Program. He was responsible for the planning, establishment and implementation of the scheme. During this period, the financial support from the United Kingdom accounted for about 90 per cent of the total cost.

The objective of the scheme was to replant coconuts at an annual target of about 1,620 hectares. Therefore, it was envisaged that after 10 years, a total of about 16,200 hectares would have been planted.

There were three main types of planting recommended:

(a) New planting - this is the planting of coconut seedlings in areas where there are no coconut trees.

(b) Replanting - this is underplanting. Seedlings are planted under existing coconut stands old enough to be replaced.

(c) Rehabilitation - this refers to the replacement of missing coconut palms in young coconut stands.

The Coconut Replanting Scheme came almost to a stand-still during 1972/73 when the United Kingdom withdrew its aid. However, the aid (loan) continued from 1974 to 1976. From then on, the funding of the scheme was taken over by the New Zealand government.

The main problem with the scheme was the lack of initiative by the farmers to maintain the coconut seedlings once they were planted. This resulted in high losses. Table A.4 and Table A.5 show acreage planted and total expenditure of the scheme.

Burgess (1981) has discussed the world situation with regards to the future potential of the coconut industry as a whole in relation to competition from other similar products. He has also discussed technical aspects relating to coconut production. This will not be repeated here.

A2.1 <u>The Banana Industry</u>

The objective of the banana industry is to efficiently produce bananas for the export market and also to satisfy the domestic requirement. The export market has been assured by the New Zealand government. New Zealand will accept all high quality bananas produced in Tonga. The banana export production reached a peak in 1967 when just under 20,000 tonnes were exported. Since then export production has decreased and reached a low of

TABLE A.4

AREAS REPLANTED

(Includes new and replanted areas)

(a) 1967 to 1970

Year	Hectares Replanted	Hectares Target	
1967	1167	1620	- 453
1968	1666	1620	+ 46
1969	1251	1620	- 369
1970	1569	1620	- 51
Total	5653	6480	- 827
Average	1413	1620	

(b) 1971/74

1971	1677	1620	+ 57
1972	1161	1620	- 459
1973	397	202	+ 195
1974	967	810	+ 157
Total	4202	4252	- 50
Average	1051	1063	

(c) 1975/79

1975	896	810	+ 86
1976	1096	1012	+ 84
1977	957	1012	- 55
1978	1013	1012	+ 1
1979	996	1012	- 16
1980	428	1012	- 584
Total	5386	5870	- 484
Average	1346	1470	

Source: Dean (1981).

TABLE A.5

TOTAL EXPENDITURE 1970-1979/80

(T$)

Item	70/71	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80
Land Clearing	21743	23867	-	18325	11050	22066	25039	24455	23520	19787
Coconut Seedlings	26497	29428	7704	22048	16854	-	29967	30331	35514	32747
Maintenance	2639	9965	-	10679	20842	20412	17622	15481	16462	18474
Vehicles, Implements	12147	9064	-	466	-	4236	-	-	28583	-
Cutting Stems	1283	2336	-	879	1295	1753	1843	1670	2089	2132
Other Charges	6851	9333	3482	4712	2884	7912	6257	11997	11755	8927
Total	71160	74929	11186	57109	52925	56379	80728	83934	117923	82067
NZ Fund (T$)							211043	66347	9342	

Source: Dean (1981).

1,400 tonnes in 1978. This decrease was due to a number of factors which included shipping problems, diseases, hurricanes and drought. The industry is heavily subsidised in the form of free chemicals and fertilizers and their application by extension officers of the M.A.F.F. In some cases, where high quality bananas are exported, there is also a subsidy on the export prices. The Kingdom's recent banana export data is presented in Table A.6.

TABLE A.6

BANANA EXPORT PRODUCTION

Year	Tonnes	No. of 25Kg Cases
1965	10321	405468
1966	14491	569289
1967	19975	784732
1968	17123	672609
1969	6884	270443
1970	4667	183364
1971	3502	137579
1972	3065	120411
1973	2851	112004
1974	2832	111257
1975	3069	120568
1976	2776	109057
1977	3236	127129
1978	1426	56021
1979	2135	83875
1980	2177	85510

Source: DP IV.

The performance of the banana industry has been below expectation. Both the yields per hectare and the production of high quality bananas remain low although the banana acreage has increased. Due to this low performance, a Banana Working Committee was established in 1979 to undertake a major review of the industry. The committee's report covered an overview of the state of the industry, problems and constraints for development and recommendations on improvements in the industry.

A3.1 Vanilla Industry

Vanilla is one of the high valued non-perishable long term crops that grows very well under coconuts. The Development Plan IV emphasizes the importance of the vanilla crop to the economy.

Vanilla, which is grown as a commercial crop, was first planted during the 1950s. However, the expansion of the industry was very slow. It was not until the 1970s that a marked increase in vanilla production was experienced. Most of the vanilla crop is planted in the Vava'u group. The planting of vanilla is done mostly by small growers who planted an average of 0.40 hectare. The area under vanilla cultivation is presented in Table A.7. The data on vanilla export production is presented in Table A.8. The marked decrease in export production experienced in 1979

TABLE A.7

AREA UNDER VANILLA CULTIVATION IN HECTARES (1980)

Category	Vava'u	Rest of Tonga
In Production	20	17
Not in Production	93	40
Shade Trees Only	20	23

Source: DP IV.

was due to a severe drought in 1978.

The curing (drying) of the vanilla beans are done by the individual farmers or through co-operatives. The marketing of the product is done

TABLE A.8

VANILLA EXPORT PRODUCTION

Year	Tonnes
1975	1.2
1976	4.1
1977	10.8
1978	8.2
1979	1.9
1980	5.1

Source: DP IV.

mostly by the Commodities Board. The increasing general trend in production has been due mainly to the favourable price for the product.

The Tonga Fourth Five Year Development Plan acknowledge the importance of the vanilla industry. It is proposed that a Vanilla Development Project be formulated and implemented at Vava'u. The main aim of the project will be the planting of about 400 hectares of vanilla crop.

A4.1 Kava

Kava is a long term, non-perishable crop that has been successfully planted as an intercrop under coconuts. Kava is grown in Tonga as a commercial crop. Kava planting is widely distributed throughout the Kingdom. The main market is the domestic market although there are potential for export to neighbouring South Pacific countries and to the countries of Western Europe. The production of kava is expected to increase in the future provided the product price remains favourable and further markets are available. The data on Kava export is presented in Table A.9.

The Fourth Development Plan stressed the importance of Kava production to the economy. The economics of kava production and available

TABLE A.9

KAVA EXPORT PRODUCTION

Year	Tonnes
1975	77.5
1976	101.2
1977	32.1
1978	10.7
1979	18.7
1980	30.8

Source: DP IV.

potential markets will be investigated during the Plan period. If the result is favourable, a Kava Development Project could be formulated. This project will be implemented in the Ha'apai group.

A5.1 Capsicum

Capsicum is grown for home consumption, local market and for export A small number of landholders supply the local and export markets using commercial horticultural techniques. The larger export growers handle all operations including the arrangement for shipping. For the small export growers all quality control, shipping and accounting is handled by the Commodities Board. The export data on capsicum is presented in Table A.10.

A6.1 Root Crops

Root crops (cassava, yams, swamp taro and xanthosoma) are grown mainly for domestic consumption. However, swamp taro, late yams and xanthosoma are increasingly becoming export crops. This is due to the growing number of Polynesians migrating to either New Zealand, Australia and the United States of America. There are farmers who grow swamp taro mainly for export. However, for the other crops, the main production is for domestic consumption. Exports are reported in Table A.11. A small number

TABLE A.10

CAPSICUM EXPORT PRODUCTION

Year	Tonnes
1975	66
1976	53
1977	42
1978	66
1979	41
1980	54

Source: DP IV and Weber & Mesui (1980).

TABLE A.11

ROOT CROPS EXPORT PRODUCTION

(tonnes)

Crops	Years					
	1975	1976	1977	1978	1979	1980
Cassava	0.4	4.4	8.7	18	4.5	8
Yams	36	29	49	42	NA	45
Swamp Taro	316	394	425	179	1347	1214
Xanthosoma	186	141	54	87	679	810

Source: Weber (1980).

of growers make their marketing arrangements for exports. However, most growers transact through the Commodities Board which carries out all the marketing arrangements. Production initiatives are left almost entirely to the farmers.

APPENDIX B

TABLE B.1

FIXED COSTS PER UNIT FARM (3.34 Hectares)

TOOLS AND EQUIPMENT

Item	Number	Cost Per Unit (T$)	Total Cost	Replacement Interval (Years)
1 Mist Blower	1	350.00	350.00	6
2 Horse	1	150.00	150.00	10
3 Cart	1	350.00	350.00	15
4 Cane-knife	3	3.00	9.00	5
5 Bush-hoe	3	5.00	15.00	5
6 Digging Spade	3	10.00	30.00	5
7 Digging Fork	2	10.00	20.00	5
8 Axe	1	8.00	8.00	5
9 Gum Boots	3 pr	10.00	30.00	2
10 Respirator	1	4.00	4.00	2
11 Empty Drums	2	6.00	12.00	2
12 Copra Knife	3	3.00	9.00	5
13 Gloves	3 pr	3.00	9.00	1
14 Wheelbarrow	1	60.00	60.00	5
15 Desuckering Tool	2	6.00	12.00	7
16 Scab Moth Injector	1	7.00	7.00	7

Notes:
a Item 12 is applicable to coconut production only.
b Items 15 and 16 are applicable to banana production only.
c Items 1 and 10 are applicable to swamp taro, capsicum, yams and banana production only.
d The rest of the items are applicable to the production of all the crops considered in the cash flows.

APPENDIX C

TABLE C.1

VALUE OF SOME OF TONGA'S AGRICULTURAL EXPORTS (T$'000) - CROPS CONSIDERED IN THE CASH FLOWS

Commodity	Years					
	1975	1976	1977	1978	1979	1980
Coconut Products	3508	2078	4922	3776	3610	NA
Bananas	307	276	402	182	306	312
Vanilla	13	42	165	181	47	261
Kava	137	197	99	40	60	108
Cassava	0.06	0.4	2.3	5.9	1.7	NA
Yams	7	7	25	18	42	64
Swamp Taro	78	126	246	60	395	271
Xanthosoma	27	23	17	23	138	152
Capsicum	31	24	14	30	15	19
Total	4108.06	2773.4	5892.3	4315.9	4614.7	

APPENDIX D

THE RELATIONSHIP BETWEEN MAXIMISING SUM OF NET PRESENT VALUE AND MAXIMISING NET WORTH

The maximisation of net present value can be shown as:

$$\max \sum_{j=1}^{n} dj.Pj \qquad (1)$$

where Pj is the farm profit in year j of the planting period j = (1...n) and dj is the discount factor for year j.

Profit is analysed as:

$$Pj = Rj - (Cj + Dj) \qquad (2)$$

where Rj is gross returns in year j, Cj is cash costs in year j, and Dj is non-cash costs or depreciation in year j.

Restating equation (2) we obtain cash surplus equal to profit plus depreciation.

$$Rj - Cj = Pj + Dj \qquad (3)$$

Cash surplus is assumed to be used in consumption (S) or non-recoverable uses, and investment (I) or recoverable uses. Thus:

$$Rj - Cj = Sj + Ij \qquad (4)$$

or

$$Pj + Di = Sj + Ij \qquad (5)$$

and so we obtain an expression for profit as the sum of consumption and the difference between investment and depreciation:

$$Pj = Sj + (Ij - Dj) \qquad (6)$$

The expression (Ij - Dj) represents net investment INj so that discounted profit maximisation can now be restated as:

$$\max \sum_{j=1}^{n} dj\ (Sj + INj) \qquad (7)$$

Net investment by definition is not 'consumed' until the planning horizon is reached and thus is discounted from the planning horizon and not from when it is generated. Thus equation (7) is rewritten as:

$$\max \sum_{j=1}^{n} dj\ Sj + dn \sum_{j=1}^{n} INj \tag{8}$$

where dn is the discount factor for year n, the last year in the planning period. Consumption is redefined as 'luxury' consumption in excess of basic consumption, for which a single valued personal discount factor of similar order to return on investment can be expected. The new maximand then becomes:

$$\max \sum_{j=1}^{n} dLj\ SLj + dL_n \sum_{j=1}^{n} INj \tag{9}$$

where dLj is the personal discount factor and SLj is luxury consumption. Given the personal discount rate equals the rate of return on investment and that the indifferent farmer is assumed always to invest, then luxury consumption can be dropped leaving:

$$\max dL_n \sum_{j=1}^{n} INj \tag{10}$$

and because dL_n is common to all net investments it can now be omitted such that the farmer will now:

$$\max \sum_{j=1}^{n} INj$$

that is, he will maximise the sum of net investment or terminal net worth.

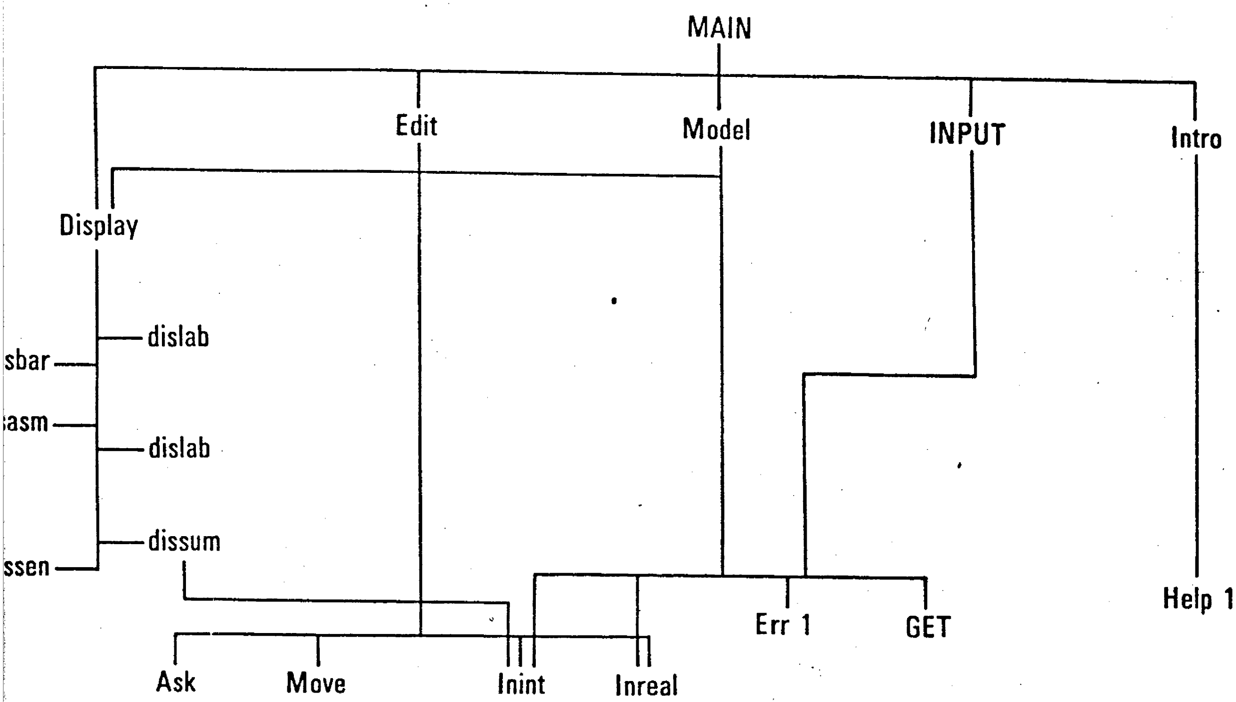
Source: Burgess 1981.

APPENDIX E

EXPLANATORY FIGURE AND TABLES FOR THE MULBUD PROGRAMMING TECHNIQUE

FIGURE E.1

THE FORMAL STRUCTURE OF MULBUD



Source: Etherington (1981).

TABLE E.1

CROP DESCRIPTORS OR ASSUMPTIONS

Descriptors	Variable Type	Comment
A. General Assumptions:		
1. Agro-climatic zone	Integer	0 - 9
2. Soil depth	Alpha	D, S: Deep, Shallow
3. Slope	Alpha	F, S: Flat, Sloping
4. Area units	Alpha	H, A: Hectare, Acre
5. Rainfall	Vector (numeric)	Rainfall per season (mm)(k)
6. Sunshine hours	Vector (numeric)	Av. hrs per day by season (k)
B. Crop Specific Assumptions:		
1. Crop name	String	Up to 12 characters
2. Starting age	Integer	Used for existing crop
3. Light interception index (LII)	"	< 100 at maturity
4. Age of maturity	"	Age of maximum LII
5. Years at maturity	"	Years at maximum LII
6. Age of senility	"	End of economic life
7. Land Use Factor (LUF)	"	% of land used at given plant spacing
8. Crop Intensity Factor (CIF)	"	Ratio of this crop stand to normal sole crop
9. Crop spacing	String (12 ch)	Describes planting system

Source: Etherington (1981).

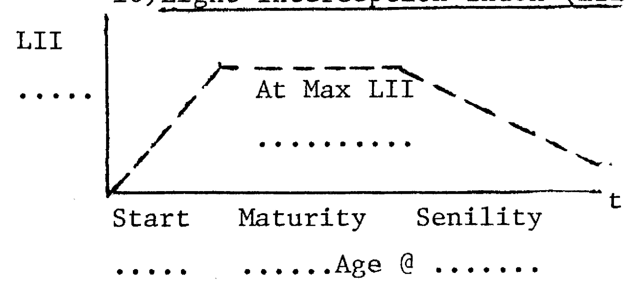
TABLE E.2(a)

LABOUR AND MATERIAL INPUTS FOR CASH FLOW ANALYSIS BY 'MULBUD' (PER ACRE/HECTARE)

Assumptions:

1) Agro-climatic Zone:................
2) Sunshine (Hrs.per season k):.......
3) Rainfall (Hrs per season k):.......
4) Mean Temperature (°C by season):...
5) Soil Depth: Deep/Shallow Slope: Flat/Sloping
6) Plant Spacing ....
7) Land Use Factor ....
8) Crop Intensity Factor ....
9) Terminal Value of Crop ....

10) Light Interception Index (LII)



TIME PERIOD $_{jk}$ (year j, season k)

Item $_i$

LABOUR INPUT (Days)
Lining & Holing
Planting
Clearing
Weeding
Fertilizing
Pest Control
Pruning

Harvesting function*=...................Processing function*=................Selling function*=...............

Family labour wage rate
Hired labour wage rate
Family labour available (days)

Yield (units)

Product price

Variable Costs Quantities in ....(Units)

Materials	Input Price
Planting	....
Clearing/ Fuel	....
Weeding	....
Fertilizer(A)	....
" (B)	....
Pesticides(A)	....
" (B)	....

Capital items (specify)
Cost per unit

* Linear functions of yield of the form a + b x Yield

MULBUD PROGRAM DATA

I	DESCRIPTORS				
	Number of Years				
	Number of Seasons				4
	Soil Depth				D
	Slope				F
	Daily Sunshine Hours Per Season				
	1) 7.0 2) 7.5 3) 7.5 4) 7.5				
	Rainfall in mm Per Season				
	1) 692 2) 347 3) 346 4) 429				
	Agrozone				1
	Unit of Area				H
	Crop Name				
	Crop Spacing				
	Starting Age				
	Age of Maturity				
	Age of Max. LII				
	Age of Senility				
	CIF				
	LUF				
	LII				
II	YIELD				
	Yield Units				KILOG
	Yield Assumptions				
III	LABOUR INPUTS				
	Lining & Holing				
	Planting & Shading				
	Clearing				
	Weeding				
	Fertilizer				
	Pest Control				
	Pruning				
	Harvest Function	A=		B=	
	Selling Function	A=		B=	
	Processing Function	A=		B=	
IV	PRICE AND COSTS				
	Price/Cost Unit				T$
	Product Price				
	Wage Rate				
	Planting Material Cost				
	Clearing Material Cost				
	Weedicide Cost				
	Estimate Value of		YR	CROP	
	Discount Rate				
	Fertilizer A				
	Cost of A				
	Fertilizer B				
	Cost of B				
	Pesticide A				
	Cost of A				
	Pesticide B				
	Cost of B				
V	MATERIAL INPUTS				
	Quantity Units				KG
	Planting Materials				
	Clearing Materials				
	Weedicides				
	Fertilizer A				
	Fertilizer B				
	Pesticide A				
	Pesticide B				
	Logical Unit				

TABLE E.3

LABOUR INPUT CATEGORIES

Item (i)	Labour Input (L_{ijk})	Variable Type
1.	Lining and holing	Numeric vector by year (j) and seasons (k)
2.	Planting/shading	"
3.	Clearing drains	"
4.	Weeding/mulching	"
5.	Fertilizer application	"
6.	Pest control	"
7.	Harvesting	Function: $a_h + b_h$ yield (for yield > 0)
8.	Processing	" : $a_p + b_p$ yield (")
9.	Selling	" : $a_s + b_s$ yield (")
	Family 'wage' rate (WF_{jk})	Numeric vector by year and seasons
	Hired labour wage (WH_{jk})	"
	Family labour <u>supply</u> (FL_{jk})	"

Source: Etherington (1981).

TABLE E.4

MATERIAL INPUTS, OUTPUTS AND PRICES

Item	Comment	
A. Names (strings)		
1. Monetary units	e.g. ₤, Rs, Rp, $ etc.	
2. Weight, quantity, units	lbs, kg	
3. Fertilizers	Two different fertilizers allowed for	
4. Pesticides	Two different pesticides allowed for	
B. Material Inputs	Quantities	Prices
1. Planting materials (M1)	Vector (jk)	Scalars (MP1)
2. Cleaning materials (M2)	"	" (MP2)
3. Weedicide (M3)	"	" (MP3)
4. Fertilizers (A & B) (M4, M5)	"	" (MP4, MP5)
5. Pesticides (A & B) (M6, M7)	"	" (MP6, MP7)
C. Discount Rates		
1. User defined a. for economic analysis		" (RA)
b. for production credit		" (IA)
2. Sensitivity analysis	8, 16, 24, 32%	Scalars
D. Output		
1. Yield (Y_{jk})	Vector (jk)	Vector (P_{jk})
2. Terminal Value (TV_{J+1})	Scalar	

Source: Etherington (1981).

TABLE E.5

MULBUD: STRUCTURAL EQUATIONS AND DEFINITIONS

Item		Equation	
Total Labour by Year (j) and Season (k)		$TL_{jk} = \sum_{i}^{9} L_{ijk}$	(for operations i =1,...,9)
Sum Total of all Labour	(STL)	$STL = \sum_{j}^{J} \sum_{k}^{k} TL_{jk}$	
Hired Labour	(HL_{jk})	$HL_{jk} = TL_{jk} - FL_{jk}$	(iff $TL_{jk} > FL_{jk}$)
Total Labour Costs 1	($TLC1_{jk}$)	$TLC1_{jk} = TL_{jk} \cdot WH_{jk}$	(only for single crop mode)
Total Labour Costs 2	($TLC2_{jk}$)	$TLC2_{jk} = HL_{jk} \cdot WH_{jk} + (TL_{jk} - HL_{jk}) \cdot WF_{jk}$	
Material Costs	(TMC_{jk})	$TMC_{jk} = \sum_{i=1}^{7} (M_{ijk} \cdot MP_{i})$	
Gross Revenue	(GR_{jk})	$GR_{jk} = Y_{jk} \cdot P_{jk}$	
Net Revenue	(NR_{jk})	$NR_{jk} = GR_{jk} - TMC_{jk} - TLC1_{jk}$	(for sole crop)
	or	$NR_{jk} = GR_{jk} - TMC_{jk} - TLC2_{jk}$	(for crop models)

TABLE E.5 (Cont'd)

Cash Flow[1]	(CSH_{jk})	$CSH_{jk} = GR_{jk} - TMC_{jk} - (HL_{jk} \cdot WH_{jh}) + LOAN - REPAY_{j+G,k}$
Loan Repayments[1]	($REPAY_{j+G,k}$)	$REPAY_{j+G,k} = LOAN\ (1+IA)^{G}\ ((1+IS)^{K*})/((1+IS)^{K*} - 1)$
		Where G is the grace period in years, K* is the number of equal seasonal repayments. IA is the annual interest rate on the loan, and IS is the equivalent seasonal rate, $IS = (1+IA)^{1/K} - 1$
Annual Interest Rate		RA
Seasonal Interest Rate		$RS = (1+RA)^{1/K} - 1$ (for K seasons per year)
Light Interception Index (LII)		$LII_{jk} = (LII/AGE\ 1) \cdot t$ for $t \leq AGE\ 2$
		Where AGE 1 is age of maturity and t is sequential time
		$LII_{jk} = (LII/(AGE\ 3 - AGE\ 2))t$ for $t > AGE\ 2$
		Where AGE 3 is age of senility

In the Modelling mode all crops can be scaled down and can start in any year of the top, shade, crop (T). The scaling is indicated in the following by the w parameters ($W_w^T + \sum_h^H w^h \leq 1$). The time shift is shown by the crop specific years: j(h) for intercrop h.

Pooled LII	($PLII_{jk}$)	$PLII_{jk} = w^T LII_{jk}^T + \sum_h^H w^h LII_{j(h)k}^h \cdot (TLUF_{jk})$
		Where T is the top, shade, crop and there are h=1,...H intercrops

TABLE E.5 (Cont'd)

Total Land Use Factor ($TLUF_j$)	$TLUF_j = w^T LUF^T + w^h LUF^h_{j(h)}$ Where J(h) is the year of introducing intercrop h
Total Crop Intensity Factor ($TCIF_j$)	$TCIF_j = w^T CIF^T + w^h CIF^h_{j(h)}$ Where J(h) is the year of introducing intercrop h
<u>Interaction Factors</u> (iff $TLUF > LUF^T$)	
Pooled Weeding Labour ($PWEDL_{jk}$)	$PWEDL_{jk} = (w^T WEDL^T_{jk} + \sum_h^H w^h WEDL^h_{j(h)k}) \cdot \ (1-TULF.KW)$ Where KW is the weeding labour interaction factor ($0 \leq KW \leq 1$)
Pooled Fertilizer Labour ($PFRTL_{jk}$)	$PFRTL_{jk} = (w^T FRTL^T_{jk} + \sum_h^H w^h FRTL^h_{j(h)k}) \cdot$ $(1 - TLUF_j \cdot KF)$ Where KF is the fertilizer labour input interaction factor ($0 \leq KF \leq 1$)
Pooled Pesticide Labour ($PPSTL_{jk}$)	$PSTL_{jk} = (w^T PSTL^T + \sum_h^H w^h PSTL^h_{j(h)k}) \cdot$ $(1 - TLUF_j \cdot KP)$ Where KP is the pest control labour input interaction factor ($0 \leq KP \leq 1$)

Note: 1 Standard discounting equations are not shown except for that relating to loan repayments.

Source: Etherington (1981)

APPENDIX F

HARVESTING, PROCESSING AND SELLING LABOUR FUNCTIONS

The harvesting, processing and selling labour requirements for the different crops are assumed to be a linear function of the form A + B x output. These are presented in Table F.1.

TABLE F.1

Crop	Harvesting Function A	Harvesting Function B	Processing Function A	Processing Function B	Selling Function A	Selling Function B
Coconuts	0.50	0.0500	3.0	0.20	0.5	0.02
Cassava	0.25	0.002	0.02	0.0005	0.5	0.0004
Yams	0.25	0.006	0.02	0.0005	0.5	0.0007
Swamp Taro	0.25	0.003	0.05	0.002	0.5	0.0004
Xanthosoma	0.25	0.0028	0.02	0.0004	0.5	0.0008
Capsicum	0.25	0.005	0.02	0.003	0.5	0.001
Kava	0.25	0.004	0.20	0.002	0.5	0.001
Banana	0.25	0.0012	0.04	0.0025	0.5	0.0003
Vanilla	0.25	0.0056	14.0	0.19	0	0

TABLE G.1

CROP: TONGA INTERCROPPING 1A   AREA UNIT: Hectare

! S U M M A R Y   R E S U L T S !

* * YEAR	SEASON	TOTAL LABOUR (DAYS)	* VARIABLE COSTS * LABOUR COSTS (T$)	MATERIAL COSTS (T$)	TOTAL COSTS (T$)	GROSS REV-ENUE (T$)	NET REVENUE (T$)	N.R./ LABOUR DAY (T$)	OUTPUT (100NUT)	PRICE (T$)
1	1	68.16	190.84	418.94	609.78	77.00	-532.78	-7.82	15.	5.00
	2	37.16	118.91	307.44	426.35	77.00	-349.35	-9.40	15.	5.00
	3	31.16	99.71	205.04	304.75	77.00	-227.75	-7.31	15.	5.00
	4	30.16	84.44	313.84	398.28	77.00	-321.28	-10.65	15.	5.00
2	1	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.00
	2	49.50	158.39	290.65	449.04	599.30	150.26	3.04	11.	5.00
	3	47.50	151.99	103.00	254.99	599.30	344.31	7.25	11.	5.00
	4	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.00
3	1	55.82	156.29	290.65	446.94	754.70	307.76	5.51	12.	5.00
	2	55.82	178.62	290.65	469.27	754.70	285.43	5.11	12.	5.00
	3	53.82	172.22	103.00	275.22	754.70	479.48	8.91	12.	5.00
	4	55.82	156.29	290.65	446.94	754.70	307.76	5.51	12.	5.00
4	1	51.73	144.85	290.65	435.50	659.00	223.50	4.32	8.	5.00
	2	51.73	165.54	290.65	456.19	659.00	202.81	3.92	8.	5.00
	3	49.73	159.14	103.00	262.14	659.00	396.86	7.98	8.	5.00
	4	51.73	144.85	290.65	435.50	659.00	223.50	4.32	8.	5.00
5	1	48.15	134.81	290.65	425.46	574.30	148.84	3.09	6.	5.00
	2	48.15	154.07	290.65	444.72	574.30	129.58	2.69	6.	5.00
	3	46.15	147.67	103.00	250.67	574.30	323.63	7.01	6.	5.00
	4	48.15	134.81	290.65	425.46	574.30	148.84	3.09	6.	5.00
6	1	45.88	128.46	280.65	409.11	510.60	101.49	2.21	10.	5.00
	2	45.88	146.81	280.65	427.46	510.60	83.14	1.81	10.	5.00
	3	43.88	140.41	93.00	233.41	510.60	277.19	6.32	10.	5.00
	4	45.88	128.46	280.65	409.11	510.60	101.49	2.21	10.	5.00
7	1	44.16	123.63	280.65	404.28	467.50	63.22	1.43	10.	5.00
	2	42.37	135.59	280.65	416.24	422.90	6.66	0.16	10.	5.00
	3	37.71	120.66	178.25	298.91	306.30	7.39	0.20	10.	5.00
	4	19.56	54.75	195.40	250.15	227.50	-22.65	-1.16	10.	5.00
8	1	6.32	17.70	5.00	22.70	43.00	20.30	3.21	9.	5.00
	2	6.32	20.23	5.00	25.23	43.00	17.77	2.81	9.	5.00
	3	6.32	20.23	5.00	25.23	43.00	17.77	2.81	9.	5.00
	4	6.32	17.70	5.00	22.70	43.00	20.30	3.21	9.	5.00
9	1	65.92	184.57	318.94	503.51	35.50	-468.01	-7.10	7.	5.00
	2	34.92	111.73	207.44	319.17	35.50	-283.67	-8.12	7.	5.00
	3	28.92	92.53	105.04	197.57	35.50	-162.07	-5.60	7.	5.00
	4	27.92	78.17	213.84	292.01	35.50	-256.51	-9.19	7.	5.00
10	1	48.90	136.93	290.65	427.58	588.30	160.72	3.29	8.	5.00
	2	48.90	156.49	290.65	447.14	588.30	141.16	2.89	8.	5.00
	3	46.90	150.09	103.00	253.09	588.30	335.21	7.15	8.	5.00
	4	48.90	136.93	290.65	427.58	588.30	160.72	3.29	8.	5.00
11	1	54.68	153.12	290.65	443.77	733.70	289.93	5.30	8.	5.0
	2	54.68	174.99	290.65	465.64	733.70	268.06	4.90	8.	5.0
	3	52.68	168.59	103.00	271.59	733.70	462.11	8.77	8.	5.0
	4	54.68	153.12	290.65	443.77	733.70	289.93	5.30	8.	5.0
12	1	51.73	144.85	290.65	435.50	659.00	223.50	4.32	8.	5.0
	2	51.73	165.54	290.65	456.19	659.00	202.81	3.92	8.	5.0
	3	49.73	159.14	103.00	262.14	659.00	396.86	7.98	8.	5.0
	4	51.73	144.85	290.65	435.50	659.00	223.50	4.32	8.	5.0

! O V E R A L L   S U M M A R Y !

Sum of Net Present Value = T$ 3492.84 at a Discount Rate of 6.00%
The amortized values are T$ 416.62 per year,
or T$ 101.89 per season.
Total Labour Use over the whole time period is 2102.94 Labour days
The average ANNUAL labour use is 175.24 labour days,
and the average SEASONAL labour use is 43.81 labour days.
SNPV per Labour day = T$ 1.66
and SNPV per Land Use Factor = T$ 4109.23

CROP: TONGA INTERCROPPING 2A AREA UNIT: Hectare

S U M M A R Y   R E S U L T S

YEAR	SEASON	TOTAL LABOUR (DAYS)	VARIABLE COSTS: LABOUR COSTS (T$)	VARIABLE COSTS: MATERIAL COSTS (T$)	VARIABLE COSTS: TOTAL COSTS (T$)	GROSS REVENUE (T$)	NET REVENUE (T$)	N.R./ LABOUR DAY (T$)	OUTPUT (100NUT)	PRIC (T$
1	1	10.16	28.44	193.00	221.44	77.00	-144.44	-14.22	15.	5.0
	2	80.16	256.51	199.00	455.51	77.00	-378.51	-4.72	15.	5.0
	3	53.16	170.11	105.00	275.11	77.00	-198.11	-3.73	15.	5.0
	4	48.16	134.84	105.00	239.84	77.00	-162.84	-3.38	15.	5.0
2	1	38.84	108.74	5.00	113.74	52.50	-61.24	-1.58	11.	5.0
	2	26.84	85.87	5.00	90.87	52.50	-38.37	-1.43	11.	5.0
	3	37.84	121.07	5.00	126.07	52.50	-73.57	-1.94	11.	5.0
	4	33.84	94.74	5.00	99.74	52.50	-47.24	-1.40	11.	5.0
3	1	22.24	62.27	5.00	67.27	60.00	-7.27	-0.33	12.	5.0
	2	50.24	160.77	5.00	165.77	60.00	-105.77	-2.11	12.	5.0
	3	41.24	131.97	5.00	136.97	60.00	-76.97	-1.87	12.	5.0
	4	17.24	48.27	5.00	53.27	60.00	6.73	0.39	12.	5.0
4	1	41.24	115.47	5.00	120.47	41.50	-78.97	-1.91	8.	5.0
	2	21.24	67.97	5.00	72.97	41.50	-31.47	-1.48	8.	5.0
	3	60.24	192.77	5.00	197.77	41.50	-156.27	-2.59	8.	5.0
	4	28.24	79.07	5.00	84.07	41.50	-42.57	-1.51	8.	5.0
5	1	15.49	43.36	5.00	48.36	27.50	-20.86	-1.35	6.	5.0
	2	77.56	248.20	5.00	253.20	8156.30	7903.10	101.89	6.	5.0
	3	5.49	17.55	5.00	22.55	27.50	4.95	0.90	6.	5.0
	4	5.49	15.36	5.00	20.36	27.50	7.14	1.30	6.	5.0
6	1	6.56	18.38	5.00	23.38	47.50	24.12	3.67	10.	5.0
	2	6.56	21.01	5.00	26.01	47.50	21.49	3.27	10.	5.0
	3	6.56	21.01	5.00	26.01	47.50	21.49	3.27	10.	5.0
	4	6.56	18.38	5.00	23.38	47.50	24.12	3.67	10.	5.0
7	1	8.57	23.98	93.00	116.98	47.50	-69.48	-8.11	10.	5.0
	2	78.57	251.41	99.00	350.41	47.50	-302.91	-3.86	10.	5.0
	3	51.57	165.01	5.00	170.01	47.50	-122.51	-2.38	10.	5.0
	4	46.57	130.38	5.00	135.38	47.50	-87.88	-1.89	10.	5.0
8	1	38.32	107.30	5.00	112.30	43.00	-69.30	-1.81	9.	5.0
	2	26.32	84.23	5.00	89.23	43.00	-46.23	-1.76	9.	5.0
	3	37.32	119.43	5.00	124.43	43.00	-81.43	-2.18	9.	5.0
	4	33.32	93.30	5.00	98.30	43.00	-55.30	-1.66	9.	5.0
9	1	20.92	58.57	5.00	63.57	35.50	-28.07	-1.34	7.	5.0
	2	48.92	156.53	5.00	161.53	35.50	-126.03	-2.58	7.	5.0
	3	39.92	127.73	5.00	132.73	35.50	-97.23	-2.44	7.	5.0
	4	15.92	44.57	5.00	49.57	35.50	-14.07	-0.88	7.	5.0
0	1	41.24	115.47	5.00	120.47	41.50	-78.97	-1.91	8.	5.0
	2	21.24	67.97	5.00	72.97	41.50	-31.47	-1.48	8.	5.0
	3	60.24	192.77	5.00	197.77	41.50	-156.27	-2.59	8.	5.0
	4	28.24	79.07	5.00	84.07	41.50	-42.57	-1.51	8.	5.0
1	1	16.11	45.10	5.00	50.10	39.00	-11.10	-0.69	8.	5.0
	2	78.18	250.19	5.00	255.19	8167.80	7912.61	101.21	8.	5.0
	3	6.11	19.54	5.00	24.54	39.00	14.46	2.37	8.	5.0
	4	6.11	17.10	5.00	22.10	39.00	16.90	2.77	8.	5.0
2	1	6.24	17.47	5.00	22.47	41.50	19.03	3.05	8.	5.0
	2	6.24	19.97	5.00	24.97	41.50	16.53	2.65	8.	5.0
	3	6.24	19.97	5.00	24.97	41.50	16.53	2.65	8.	5.0
	4	6.24	17.47	5.00	22.47	41.50	19.03	3.05	8.	5.0

! O V E R A L L   S U M M A R Y !

Sum of Net Present Value = T$ 8165.95 at a Discount Rate of 0.00%
The amortized values are T$ 974.01 per year,
or T$ 238.21 per season.
Total Labour Use over the whole time period is 1469.82 Labour days
The average ANNUAL labour use is 122.48 labour days,
and the average SEASONAL labour use is 30.62 labour days.
SNPV per Labour day = T$ 5.56
and SNPV per Land Use Factor = T$ 9607.00

CROP: VAVAU INTERCROPPING 1 AREA UNIT: Hectare

S U M M A R Y   R E S U L T S

YEAR	SEASON	TOTAL LABOUR (DAYS)	* V A R I A B L E C O S T S * LABOUR COSTS (T$)	MATERIAL COSTS (T$)	TOTAL COSTS (T$)	GROSS REVENUE (T$)	NET REVENUE (T$)	N.R./ LABOUR DAY (T$)	OUTPUT (100NUT)	P R I C (T$)
1	1	50.00	140.00	594.10	734.10	0.00	-734.10	-14.68	0.	5.0
	2	24.00	76.80	0.00	76.80	0.00	-76.80	-3.20	0.	5.0
	3	56.00	156.80	444.60	601.40	0.00	-601.40	-10.74	0.	5.0
2	1	36.00	100.80	16.20	117.00	0.00	-117.00	-3.25	0.	5.0
	2	35.00	112.00	0.00	112.00	0.00	-112.00	-3.20	0.	5.0
	3	35.00	98.00	0.00	98.00	0.00	-98.00	-2.80	0.	5.0
3	1	35.00	98.00	0.00	98.00	0.00	-98.00	-2.80	0.	5.0
	2	35.00	112.00	0.00	112.00	0.00	-112.00	-3.20	0.	5.0
	3	57.00	159.60	0.00	159.60	0.00	-159.60	-2.80	0.	5.0
4	1	35.00	98.00	0.00	98.00	0.00	-98.00	-2.80	0.	5.0
	2	66.47	212.70	180.00	392.70	1547.00	1154.30	17.37	0.	5.0
	3	79.00	221.20	0.00	221.20	0.00	-221.20	-2.80	0.	5.0
5	1	31.76	88.93	5.00	93.93	27.50	-66.43	-2.09	6.	5.0
	2	97.67	312.54	185.00	497.54	4668.50	4170.96	42.70	6.	5.0
	3	120.76	338.13	5.00	343.13	27.50	-315.63	-2.61	6.	5.0
6	1	32.05	89.73	5.00	94.73	32.00	-62.73	-1.96	6.	5.0
	2	149.37	488.69	185.00	673.69	9291.90	8618.21	57.70	6.	5.0
	3	121.05	338.93	5.00	343.93	32.00	-311.93	-2.58	6.	5.0
7	1	33.68	94.30	5.00	99.30	57.50	-41.80	-1.24	12.	5.0
	2	168.22	564.10	185.00	749.10	10864.40	10115.30	60.13	12.	5.0
	3	122.68	343.50	5.00	348.50	57.50	-291.00	-2.37	12.	5.0
8	1	33.62	94.12	5.00	99.12	56.50	-42.62	-1.27	11.	5.0
	2	185.38	632.72	185.00	817.72	12410.40	11592.68	62.53	11.	5.0
	3	122.62	343.32	5.00	348.32	56.50	-291.82	-2.38	11.	5.0
9	1	34.45	96.45	5.00	101.45	69.50	-31.95	-0.93	14.	5.0
	2	186.21	636.05	185.00	821.05	12423.40	11602.35	62.31	14.	5.0
	3	93.45	261.65	5.00	266.65	69.50	-197.15	-2.11	14.	5.0
0	1	34.61	96.90	5.00	101.90	72.00	-29.90	-0.86	14.	5.0
	2	151.93	498.93	125.00	623.93	9331.90	8707.97	57.31	14.	5.0
	3	93.61	262.10	5.00	267.10	72.00	-195.10	-2.08	14.	5.0
1	1	35.92	100.58	5.00	105.58	92.50	-13.08	-0.36	19.	5.0
	2	136.02	435.30	125.00	560.30	7805.40	7245.10	53.26	19.	5.0
	3	80.92	226.58	5.00	231.58	92.50	-139.08	-1.72	19.	5.0
2	1	36.43	102.01	5.00	107.01	100.50	-6.51	-0.18	20.	5.0
	2	119.32	381.81	65.00	446.81	6266.40	5819.59	48.77	20.	5.0
	3	66.43	186.01	5.00	191.01	100.50	-90.51	-1.36	20.	5.0
3	1	36.75	102.91	5.00	107.91	105.50	-2.41	-0.07	21.	5.0
	2	102.66	328.52	65.00	393.52	4746.50	4352.98	42.40	21.	5.0
	3	58.75	164.51	5.00	169.51	105.50	-64.01	-1.09	21.	5.0
4	1	36.43	102.01	5.00	107.01	100.50	-6.51	-0.18	20.	5.0
	2	85.12	272.39	65.00	337.39	3194.50	2857.11	33.56	20.	5.0
	3	51.43	144.01	5.00	149.01	100.50	-48.51	-0.94	20.	5.0
5	1	36.75	102.91	5.00	107.91	105.50	-2.41	-0.07	21.	5.0
	2	68.22	218.31	5.00	223.31	1652.50	1429.19	20.95	21.	5.0
	3	31.75	88.91	5.00	93.91	105.50	11.59	0.37	21.	5.0

! O V E R A L L   S U M M A R Y !

Sum of Net Present Value = T$ 45272.78 at a Discount Rate of 6.00%
The amortized values are T$ 4661.41 per year,
or T$ 1523.72 per season.
Total Labour Use over the whole time period is 3339.50 Labour days
The average ANNUAL labour use is 222.63 labour days,
and the average SEASONAL labour use is 74.21 labour days.
SNPV per Labour day = T$ 13.56
and SNPV per Land Use Factor = T$ 53262.09

CROP: tonga INTERCROPPING 2C AREA UNIT: hectare

SUMMARY RESULTS

	SEASON	TOTAL LABOUR (DAYS)	* VARIABLE COSTS * LABOUR COSTS (T$)	MATERIAL COSTS (T$)	TOTAL COSTS (T$)	GROSS REVENUE (T$)	NET REVENUE (T$)	N.R./ LABOUR DAY (T$)	OUTPUT (100NUT)	PRICE (T$)
	1	14.00	39.20	99.20	138.40	0.00	-138.40	-9.89	0.	5.00
	2	76.00	243.20	99.00	342.20	0.00	-342.20	-4.50	0.	5.00
	3	49.00	156.80	5.00	161.80	0.00	-161.80	-3.30	0.	5.00
	4	44.00	123.20	5.00	128.20	0.00	-128.20	-2.91	0.	5.00
2	1	37.00	103.60	6.20	109.80	0.00	-109.80	-2.97	0.	5.00
	2	24.00	76.80	5.00	81.80	0.00	-81.80	-3.41	0.	5.00
	3	35.00	112.00	5.00	117.00	0.00	-117.00	-3.34	0.	5.00
	4	31.00	86.80	5.00	91.80	0.00	-91.80	-2.96	0.	5.00
3	1	19.00	53.20	5.00	58.20	0.00	-58.20	-3.06	0.	5.00
	2	47.00	150.40	5.00	155.40	0.00	-155.40	-3.31	0.	5.00
	3	38.00	121.60	5.00	126.60	0.00	-126.60	-3.33	0.	5.00
	4	14.00	39.20	5.00	44.20	0.00	-44.20	-3.16	0.	5.00
4	1	39.00	109.20	5.00	114.20	0.00	-114.20	-2.93	0.	5.00
	2	19.00	60.80	5.00	65.80	0.00	-65.80	-3.46	0.	5.00
	3	58.00	185.60	5.00	190.60	0.00	-190.60	-3.29	0.	5.00
	4	26.00	72.80	5.00	77.80	0.00	-77.80	-2.99	0.	5.00
5	1	15.11	42.30	5.00	47.30	20.50	-26.80	-1.77	4.	5.00
	2	77.18	246.99	5.00	251.99	8149.30	7897.31	102.32	4.	5.00
	3	5.11	16.34	5.00	21.34	20.50	-0.84	-0.16	4.	5.00
	4	5.11	14.30	5.00	19.30	20.50	1.20	0.24	4.	5.00
6	1	5.30	14.83	5.00	19.83	24.00	4.17	0.79	5.	5.00
	2	5.30	16.95	5.00	21.95	24.00	2.05	0.39	5.	5.00
	3	5.30	16.95	5.00	21.95	24.00	2.05	0.39	5.	5.00
	4	5.30	14.83	5.00	19.83	24.00	4.17	0.79	5.	5.00
7	1	8.32	23.30	93.00	116.30	43.00	-73.30	-8.81	9.	5.00
	2	78.32	250.63	99.00	349.63	43.00	-306.63	-3.91	9.	5.00
	3	51.32	164.23	5.00	169.23	43.00	-126.23	-2.46	9.	5.00
	4	46.32	129.70	5.00	134.70	43.00	-91.70	-1.98	9.	5.00
8	1	38.30	107.23	5.00	112.23	42.50	-69.73	-1.82	9.	5.00
	2	26.30	84.14	5.00	89.14	42.50	-46.64	-1.77	9.	5.00
	3	37.30	119.34	5.00	124.34	42.50	-81.84	-2.19	9.	5.00
	4	33.30	93.23	5.00	98.23	42.50	-55.73	-1.67	9.	5.00
9	1	21.84	61.14	5.00	66.14	52.50	-13.64	-0.62	11.	5.00
	2	49.84	159.47	5.00	164.47	52.50	-111.97	-2.25	11.	5.00
	3	40.84	130.67	5.00	135.67	52.50	-83.17	-2.04	11.	5.00
	4	16.84	47.14	5.00	52.14	52.50	0.36	0.02	11.	5.00
0	1	41.92	117.36	5.00	122.36	54.00	-68.36	-1.63	11.	5.00
	2	21.92	70.13	5.00	75.13	54.00	-21.13	-0.96	11.	5.00
	3	60.92	194.93	5.00	199.93	54.00	-145.93	-2.40	11.	5.00
	4	28.92	80.96	5.00	85.96	54.00	-31.96	-1.11	11.	5.00
1	1	17.73	49.63	5.00	54.63	69.00	14.37	0.81	14.	5.00
	2	79.80	255.37	5.00	260.37	8197.80	7937.43	99.46	14.	5.00
	3	7.73	24.72	5.00	29.72	69.00	39.28	5.08	14.	5.00
	4	7.73	21.63	5.00	26.63	69.00	42.37	5.48	14.	5.00
2	1	8.08	22.62	5.00	27.62	75.50	47.88	5.93	15.	5.00
	2	8.08	25.85	5.00	30.85	75.50	44.65	5.53	15.	5.00
	3	8.08	25.85	5.00	30.85	75.50	44.65	5.53	15.	5.00
	4	8.08	22.62	5.00	27.62	75.50	47.88	5.93	15.	5.00

! OVERALL SUMMARY !

Sum of Net Present Value = T$ 8425.67 at a Discount Rate of 6.00%
The amortized values are T$ 1004.99 per year,
or T$ 245.78 per season.
Total Labour Use over the whole time period is 1441.45 Labour days
The average ANNUAL labour use is 120.12 labour days,
and the average SEASONAL labour use is 30.03 labour days.
SNPV per Labour day = T$ 5.85
and SNPV per Land Use Factor = T$ 9912.55

CROP: TONGA INTERCROPPING 2D AREA UNIT: Hectar

SUMMARY RESULTS

YEAR	SEASON	TOTAL LABOUR (DAYS)	VARIABLE COSTS: LABOUR COSTS (T$)	VARIABLE COSTS: MATERIAL COSTS (T$)	VARIABLE COSTS: TOTAL COSTS (T$)	GROSS REVENUE (T$)	NET REVENUE (T$)	N.R./LABOUR DAY (T$)	OUTPUT (100NUT)	PRIC (T$
1	1	10.16	28.45	93.82	122.27	0.00	-122.27	-12.03	0.	5.0
	2	76.00	243.20	96.60	339.80	0.00	-339.80	-4.47	0.	5.0
	3	49.00	156.80	2.60	159.40	0.00	-159.40	-3.25	0.	5.0
	4	44.00	123.20	2.60	125.80	0.00	-125.80	-2.86	0.	5.0
2	1	36.52	102.26	3.22	105.48	0.00	-105.48	-2.89	0.	5.0
	2	24.00	76.80	2.60	79.40	0.00	-79.40	-3.31	0.	5.0
	3	35.00	112.00	2.60	114.60	0.00	-114.60	-3.27	0.	5.0
	4	31.00	86.80	2.60	89.40	0.00	-89.40	-2.88	0.	5.0
3	1	19.00	53.20	2.60	55.80	0.00	-55.80	-2.94	0.	5.0
	2	47.00	150.40	2.60	153.00	0.00	-153.00	-3.26	0.	5.0
	3	38.00	121.60	2.60	124.20	0.00	-124.20	-3.27	0.	5.0
	4	14.00	39.20	2.60	41.80	0.00	-41.80	-2.99	0.	5.0
4	1	39.00	109.20	2.60	111.80	0.00	-111.80	-2.87	0.	5.0
	2	19.00	60.80	2.60	63.40	0.00	-63.40	-3.34	0.	5.0
	3	58.00	185.60	2.60	188.20	0.00	-188.20	-3.24	0.	5.0
	4	26.00	72.80	2.60	75.40	0.00	-75.40	-2.90	0.	5.0
5	1	14.58	40.81	2.60	43.41	10.66	-32.75	-2.25	2.	5.0
	2	76.65	245.29	2.60	247.89	8139.46	7891.57	102.95	2.	5.0
	3	4.58	14.64	2.60	17.24	10.66	-6.58	-1.44	2.	5.0
	4	4.58	12.81	2.60	15.41	10.66	-4.75	-1.04	2.	5.0
6	1	4.67	13.09	2.60	15.69	12.48	-3.21	-0.69	2.	5.0
	2	4.67	14.96	2.60	17.56	12.48	-5.08	-1.09	2.	5.0
	3	4.67	14.96	2.60	17.56	12.48	-5.08	-1.09	2.	5.0
	4	4.67	13.09	2.60	15.69	12.48	-3.21	-0.69	2.	5.0
7	1	7.21	20.18	90.60	110.78	22.36	-88.42	-12.27	4.	5.0
	2	77.21	247.06	96.60	343.66	22.36	-321.30	-4.16	4.	5.0
	3	50.21	160.66	2.60	163.26	22.36	-140.90	-2.81	4.	5.0
	4	45.21	126.58	2.60	129.18	22.36	-106.82	-2.36	4.	5.0
8	1	37.19	104.14	2.60	106.74	22.10	-84.64	-2.28	4.	5.0
	2	25.19	80.62	2.60	83.22	22.10	-61.12	-2.43	4.	5.0
	3	36.19	115.82	2.60	118.42	22.10	-96.32	-2.66	4.	5.0
	4	32.19	90.14	2.60	92.74	22.10	-70.64	-2.19	4.	5.0
9	1	20.47	57.33	2.60	59.93	27.30	-32.63	-1.59	5.	5.0
	2	48.47	155.12	2.60	157.72	27.30	-130.42	-2.69	5.	5.0
	3	39.47	126.32	2.60	128.92	27.30	-101.62	-2.57	5.	5.0
	4	15.47	43.33	2.60	45.93	27.30	-18.63	-1.20	5.	5.0
10	1	40.52	113.45	2.60	116.05	28.08	-87.97	-2.17	6.	5.0
	2	20.52	65.65	2.60	68.25	28.08	-40.17	-1.96	6.	5.0
	3	59.52	190.45	2.60	193.05	28.08	-164.97	-2.77	6.	5.0
	4	27.52	77.05	2.60	79.65	28.08	-51.57	-1.87	6.	5.0
11	1	15.94	44.63	2.60	47.23	35.88	-11.35	-0.71	7.	5.0
	2	78.01	249.65	2.60	252.25	8164.68	7912.43	101.42	7.	5.0
	3	5.94	19.00	2.60	21.60	35.88	14.28	2.41	7.	5.0
	4	5.94	16.63	2.60	19.23	35.88	16.65	2.81	7.	5.0
12	1	6.12	17.14	2.60	19.74	39.26	19.52	3.19	8.	5.0
	2	6.12	19.58	2.60	22.18	39.26	17.08	2.79	8.	5.0
	3	6.12	19.58	2.60	22.18	39.26	17.08	2.79	8.	5.0
	4	6.12	17.14	2.60	19.74	39.26	19.52	3.19	8.	5.0

! OVERALL SUMMARY !

Sum of Net Present Value = T$ 7887.10 at a Discount Rate of 6.00%
The amortized values are T$ 940.75 per year,
or T$ 230.07 per season.
Total Labour Use over the whole time period is 1397.63 Labour days
The average ANNUAL labour use is 116.47 labour days,
and the average SEASONAL labour use is 29.12 labour days.
SNPV per Labour day = T$ 5.64
and SNPV per Land Use Factor = T$ 10804.24

CROP: TONGA INTERCROPPING 2E AREA UNIT: Hectare

SUMMARY RESULTS

YEAR	SEASON	TOTAL LABOUR (DAYS)	VARIABLE COSTS: LABOUR COSTS (T$)	VARIABLE COSTS: MATERIAL COSTS (T$)	VARIABLE COSTS: TOTAL COSTS (T$)	GROSS REV-ENUE (T$)	NET REVENUE (T$)	N.R./ LABOUR DAY (T$)	OUTPUT (100NUT)	PRICE (T$)
1	1	10.49	29.38	108.49	137.87	0.00	-137.87	-13.14	0.	5.00
	2	88.00	281.60	112.27	393.87	0.00	-393.87	-4.48	0.	5.00
	3	56.50	180.80	2.60	183.40	0.00	-183.40	-3.25	0.	5.00
	4	50.67	141.87	2.60	144.47	0.00	-144.47	-2.85	0.	5.00
2	1	41.85	117.19	3.22	120.41	0.00	-120.41	-2.88	0.	5.00
	2	27.33	87.47	2.60	90.07	0.00	-90.07	-3.30	0.	5.00
	3	40.17	128.53	2.60	131.13	0.00	-131.13	-3.26	0.	5.00
	4	35.50	99.40	2.60	102.00	0.00	-102.00	-2.87	0.	5.00
3	1	21.50	60.20	2.60	62.80	0.00	-62.80	-2.92	0.	5.00
	2	54.17	173.33	2.60	175.93	0.00	-175.93	-3.25	0.	5.00
	3	43.67	139.73	2.60	142.33	0.00	-142.33	-3.26	0.	5.00
	4	15.67	43.87	2.60	46.47	0.00	-46.47	-2.97	0.	5.00
4	1	44.83	125.53	2.60	128.13	0.00	-128.13	-2.86	0.	5.00
	2	21.50	68.80	2.60	71.40	0.00	-71.40	-3.32	0.	5.00
	3	67.00	214.40	2.60	217.00	0.00	-217.00	-3.24	0.	5.00
	4	29.67	83.07	2.60	85.67	0.00	-85.67	-2.89	0.	5.00
5	1	16.24	45.48	2.60	48.08	10.66	-37.42	-2.30	2.	5.00
	2	88.51	283.22	2.60	285.82	9494.26	9208.44	104.04	2.	5.00
	3	4.58	14.64	2.60	17.24	10.66	-6.58	-1.44	2.	5.00
	4	4.58	12.81	2.60	15.41	10.66	-4.75	-1.04	2.	5.00
6	1	4.67	13.09	2.60	15.69	12.48	-3.21	-0.69	2.	5.00
	2	4.67	14.96	2.60	17.56	12.48	-5.08	-1.09	2.	5.00
	3	4.67	14.96	2.60	17.56	12.48	-5.08	-1.09	2.	5.00
	4	4.67	13.09	2.60	15.69	12.48	-3.21	-0.69	2.	5.00
7	1	7.37	20.65	97.93	118.58	22.36	-96.22	-13.05	4.	5.00
	2	83.21	266.26	104.43	370.70	22.36	-348.34	-4.19	4.	5.00
	3	53.96	172.66	2.60	175.26	22.36	-152.90	-2.83	4.	5.00
	4	48.54	135.91	2.60	138.51	22.36	-116.15	-2.39	4.	5.00
8	1	39.86	111.61	2.60	114.21	22.10	-92.11	-2.31	4.	5.00
	2	26.86	85.95	2.60	88.55	22.10	-66.45	-2.47	4.	5.00
	3	38.78	124.09	2.60	126.69	22.10	-104.59	-2.70	4.	5.00
	4	34.44	96.44	2.60	99.04	22.10	-76.94	-2.23	4.	5.00
9	1	21.72	60.83	2.60	63.43	27.30	-36.13	-1.66	5.	5.00
	2	52.06	166.58	2.60	169.18	27.30	-141.88	-2.73	5.	5.00
	3	42.31	135.38	2.60	137.98	27.30	-110.68	-2.62	5.	5.00
	4	16.31	45.66	2.60	48.26	27.30	-20.96	-1.29	5.	5.00
10	1	43.43	121.61	2.60	124.21	28.08	-96.13	-2.21	6.	5.00
	2	21.77	69.65	2.60	72.25	28.08	-44.17	-2.03	6.	5.00
	3	64.02	204.85	2.60	207.45	28.08	-179.37	-2.80	6.	5.00
	4	29.35	82.18	2.60	84.78	28.08	-56.70	-1.93	6.	5.00
11	1	16.77	46.96	2.60	49.56	35.88	-13.68	-0.82	7.	5.00
	2	83.94	268.61	2.60	271.21	8842.08	8570.87	102.10	7.	5.00
	3	5.94	19.00	2.60	21.60	35.88	14.28	2.41	7.	5.00
	4	5.94	16.63	2.60	19.23	35.88	16.65	2.81	7.	5.00
12	1	6.12	17.14	2.60	19.74	39.26	19.52	3.19	8.	5.00
	2	6.12	19.58	2.60	22.18	39.26	17.08	2.79	8.	5.00
	3	6.12	19.58	2.60	22.18	39.26	17.08	2.79	8.	5.00
	4	6.12	17.14	2.60	19.74	39.26	19.52	3.19	8.	5.00

! OVERALL SUMMARY !

Sum of Net Present Value = T$ 8907.63 at a Discount Rate of 6.00%
The amortized values are T$ 1062.48 per year,
or T$ 259.84 per season.
Total Labour Use over the whole time period is 1542.16 Labour days
The average ANNUAL labour use is 128.51 labour days,
and the average SEASONAL labour use is 32.13 labour days.
SNPV per Labour day = T$ 5.78
and SNPV per Land Use Factor = T$ 10732.08

CROP: TONGA INTERCROPPING 3 AREA UNIT: Hectare

SUMMARY RESULTS

YEAR	SEASON	TOTAL LABOUR (DAYS)	* VARIABLE COSTS * LABOUR COSTS (T$)	MATERIAL COSTS (T$)	TOTAL COSTS (T$)	GROSS REVENUE (T$)	NET REVENUE (T$)	N.R./ LABOUR DAY (T$)	YIELD (100NUT)	PRICE (T$)
1	1	9.24	25.87	193.00	218.87	60.00	-158.87	-17.19	12.	5.0
	2	79.24	253.57	199.00	452.57	60.00	-392.57	-4.95	12.	5.0
	3	52.24	167.17	105.00	272.17	60.00	-212.17	-4.06	12.	5.0
	4	47.24	132.27	105.00	237.27	60.00	-177.27	-3.75	12.	5.0
2	1	39.38	110.25	105.00	215.25	62.50	-152.75	-3.88	13.	5.0
	2	27.38	87.60	105.00	192.60	62.50	-130.10	-4.75	13.	5.0
	3	38.38	122.80	105.00	227.80	62.50	-165.30	-4.31	13.	5.0
	4	34.38	96.25	5.00	101.25	62.50	-38.75	-1.13	13.	5.0
3	1	21.92	61.36	5.00	66.36	54.00	-12.36	-0.56	11.	5.0
	2	49.92	159.73	5.00	164.73	54.00	-110.73	-2.22	11.	5.0
	3	40.92	130.93	5.00	135.93	54.00	-81.93	-2.00	11.	5.0
	4	16.92	47.36	5.00	52.36	54.00	1.64	0.10	11.	5.0
4	1	41.67	116.68	5.00	121.68	49.50	-72.18	-1.73	10.	5.0
	2	21.67	69.35	5.00	74.35	49.50	-24.85	-1.15	10.	5.0
	3	60.67	194.15	5.00	199.15	49.50	-149.65	-2.47	10.	5.0
	4	28.67	80.28	5.00	85.28	49.50	-35.78	-1.25	10.	5.0
5	1	16.73	46.84	5.00	51.84	50.50	-1.34	-0.08	10.	5.0
	2	78.80	252.17	5.00	257.17	8179.30	7922.13	100.53	10.	5.0
	3	6.73	21.53	5.00	26.53	50.50	23.97	3.56	10.	5.0
	4	6.73	18.84	5.00	23.84	50.50	26.66	3.96	10.	5.0
6	1	67.00	187.59	318.94	506.53	55.50	-451.03	-6.73	11.	5.0
	2	36.00	115.19	207.44	322.63	55.50	-267.13	-7.42	11.	5.0
	3	30.00	95.99	105.04	201.03	55.50	-145.53	-4.85	11.	5.0
	4	29.00	81.19	213.84	295.03	55.50	-239.53	-8.26	11.	5.0
7	1	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.0
	2	49.50	158.39	290.65	449.04	599.30	150.26	3.04	11.	5.0
	3	47.50	151.99	103.00	254.99	599.30	344.31	7.25	11.	5.0
	4	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.0
8	1	55.95	156.67	290.65	447.32	757.20	309.88	5.54	13.	5.0
	2	55.95	179.05	290.65	469.70	757.20	287.50	5.14	13.	5.0
	3	53.95	172.65	103.00	275.65	757.20	481.55	8.93	13.	5.0
	4	55.95	156.67	290.65	447.32	757.20	309.88	5.54	13.	5.0
9	1	53.11	148.70	290.65	439.35	684.50	245.15	4.62	13.	5.0
	2	53.11	169.95	290.65	460.60	684.50	223.90	4.22	13.	5.0
	3	51.11	163.55	103.00	266.55	684.50	417.95	8.18	13.	5.0
	4	53.11	148.70	290.65	439.35	684.50	245.15	4.62	13.	5.0
0	1	49.52	138.67	290.65	429.32	599.80	170.48	3.44	11.	5.0
	2	49.52	158.48	290.65	449.13	599.80	150.67	3.04	11.	5.0
	3	47.52	152.08	103.00	255.08	599.80	344.72	7.25	11.	5.0
	4	49.52	138.67	290.65	429.32	599.80	170.48	3.44	11.	5.0
1	1	45.85	128.39	280.65	409.04	510.10	101.06	2.20	9.	5.0
	2	45.85	146.73	280.65	427.38	510.10	82.72	1.80	9.	5.0
	3	43.85	140.33	93.00	233.33	510.10	276.77	6.31	9.	5.0
	4	45.85	128.39	280.65	409.04	510.10	101.06	2.20	9.	5.0
2	1	44.05	123.33	280.65	403.98	465.50	61.52	1.40	9.	5.0
	2	42.26	135.24	280.65	415.89	420.90	5.01	0.12	9.	5.0
	3	37.60	120.32	178.25	298.57	304.30	5.73	0.15	9.	5.0
	4	19.45	54.45	195.40	249.85	225.50	-24.35	-1.25	9.	5.0

! OVERALL SUMMARY !

Sum of Net Present Value = T$ 6707.64 at a Discount Rate of 6.00%
The amortized values are T$ 800.07 per year,
or T$ 195.67 per season.
Total Labour Use over the whole time period is 2029.88 Labour days
The average ANNUAL labour use is 169.16 labour days,
and the average SEASONAL labour use is 42.29 labour days.
SNPV per Labour day = T$ 3.30
and SNPV per Land Use Factor = T$ 7891.34

CROP: TONGA INTERCROPPING 4 AREA UNIT: Hecta

S U M M A R Y   R E S U L T S

**YEAR	SEASON	TOTAL LABOUR (DAYS)	* V A R I A B L E C O S T S * LABOUR COSTS (T$)	MATERIAL COSTS (T$)	TOTAL COSTS (T$)	GROSS REV-ENUE (T$)	NET REVENUE (T$)	N.R./ LABOUR DAY (T$)	OUTPUT (100NUT)	P R I (T
1	1	67.24	188.27	418.94	607.21	60.00	-547.21	-8.14	12.	5.
	2	36.24	115.97	307.44	423.41	60.00	-363.41	-10.03	12.	5.
	3	30.24	96.77	205.04	301.81	60.00	-241.81	-8.00	12.	5.
	4	29.24	81.87	313.84	395.71	60.00	-335.71	-11.48	12.	5.
2	1	50.04	140.10	390.65	530.75	609.30	78.55	1.57	13.	5.
	2	50.04	160.12	390.65	550.77	609.30	58.53	1.17	13.	5.
	3	48.04	153.72	203.00	356.72	609.30	252.58	5.26	13.	5.
	4	50.04	140.10	290.65	430.75	609.30	178.55	3.57	13.	5.
3	1	55.49	155.38	290.65	446.03	748.70	302.67	5.45	11.	5.
	2	55.49	177.58	290.65	468.23	748.70	280.47	5.05	11.	5.
	3	53.49	171.18	103.00	274.18	748.70	474.52	8.87	11.	5.
	4	55.49	155.38	290.65	446.03	748.70	302.67	5.45	11.	5.
4	1	52.16	146.06	290.65	436.71	667.00	230.29	4.41	10.	5.
	2	52.16	166.92	290.65	457.57	667.00	209.43	4.01	10.	5.
	3	50.16	160.52	103.00	263.52	667.00	403.48	8.04	10.	5.
	4	52.16	146.06	290.65	436.71	667.00	230.29	4.41	10.	5.
5	1	49.39	138.29	290.65	428.94	597.30	168.36	3.41	10.	5.
	2	49.39	158.04	290.65	448.69	597.30	148.61	3.01	10.	5.
	3	47.39	151.64	103.00	254.64	597.30	342.66	7.23	10.	5.
	4	49.39	138.29	290.65	428.94	597.30	168.36	3.41	10.	5.
6	1	46.31	129.67	280.65	410.32	518.60	108.28	2.34	11.	5.
	2	46.31	148.20	280.65	428.85	518.60	89.75	1.94	11.	5.
	3	44.31	141.80	93.00	234.80	518.60	283.80	6.40	11.	5.
	4	46.31	129.67	280.65	410.32	518.60	108.28	2.34	11.	5.
7	1	44.43	124.39	280.65	405.04	472.50	67.46	1.52	11.	5.
	2	42.64	136.45	280.65	417.10	427.90	10.80	0.25	11.	5.
	3	37.98	121.53	178.25	299.78	311.30	11.52	0.30	11.	5.
	4	19.83	55.51	195.40	250.91	232.50	-18.41	-0.93	11.	5.
8	1	9.38	26.25	93.00	119.25	62.50	-56.75	-6.05	13.	5.
	2	79.38	254.00	99.00	353.00	62.50	-290.50	-3.66	13.	5.
	3	52.38	167.60	5.00	172.60	62.50	-110.10	-2.10	13.	5.
	4	47.38	132.65	5.00	137.65	62.50	-75.15	-1.59	13.	5.
9	1	39.62	110.93	5.00	115.93	67.00	-48.93	-1.24	13.	5.
	2	27.62	88.38	5.00	93.38	67.00	-26.38	-0.96	13.	5.
	3	38.62	123.58	5.00	128.58	67.00	-61.58	-1.59	13.	5.
	4	34.62	96.93	5.00	101.93	67.00	-34.93	-1.01	13.	5.
10	1	21.86	61.21	5.00	66.21	53.00	-13.21	-0.60	11.	5.
	2	49.86	159.56	5.00	164.56	53.00	-111.56	-2.24	11.	5.
	3	40.86	130.76	5.00	135.76	53.00	-82.76	-2.03	11.	5.
	4	16.86	47.21	5.00	52.21	53.00	0.79	0.05	11.	5.
11	1	41.54	116.31	5.00	121.31	47.00	-74.31	-1.79	9.	5.
	2	21.54	68.92	5.00	73.92	47.00	-26.92	-1.25	9.	5.
	3	60.54	193.72	5.00	198.72	47.00	-151.72	-2.51	9.	5.
	4	28.54	79.91	5.00	84.91	47.00	-37.91	-1.33	9.	5.
12	1	16.46	46.08	5.00	51.08	45.50	-5.58	-0.34	9.	5.
	2	78.53	251.31	5.00	256.31	8174.30	7917.99	100.82	9.	5.
	3	6.46	20.66	5.00	25.66	45.50	19.84	3.07	9.	5.
	4	6.46	18.08	5.00	23.08	45.50	22.42	3.47	9.	5.

! O V E R A L L   S U M M A R Y !

Sum of Net Present Value = T$ 5749.16 at a Discount Rate of 0.00
The amortized values are T$ 685.74 per year,
or T$ 167.71 per season.
Total Labour Use over the whole time period is 2029.88 Labour days
The average ANNUAL labour use is 169.16 labour days,
and the average SEASONAL labour use is 42.29 labour days.
SNPV per Labour day = T$ 2.83
and SNPV per Land Use Factor = T$ 6763.72

CROP: TONGA INTERCROPPING 5 AREA UNIT: Hectar

S U M M A R Y   R E S U L T S

YEAR	SEASON	TOTAL LABOUR (DAYS)	VARIABLE COSTS: LABOUR COSTS (T$)	VARIABLE COSTS: MATERIAL COSTS (T$)	VARIABLE COSTS: TOTAL COSTS (T$)	GROSS REV-ENUE (T$)	NET REVENUE (T$)	N.R./ LABOUR DAY (T$)	OUTPUT (100NUT)	PRIC (T$
1	1	38.24	107.07	305.97	413.04	60.00	-353.04	-9.23	12.	5.0
	2	57.74	184.77	253.22	437.99	60.00	-377.99	-6.55	12.	5.0
	3	41.24	131.97	155.02	286.99	60.00	-226.99	-5.50	12.	5.0
	4	38.24	107.07	209.42	316.49	60.00	-256.49	-6.71	12.	5.0
2	1	45.10	126.28	247.82	374.11	335.90	-38.21	-0.85	13.	5.0
	2	39.10	125.12	247.82	372.95	335.90	-37.05	-0.95	13.	5.0
	3	43.60	139.52	154.00	293.52	335.90	42.38	0.97	13.	5.0
	4	42.60	119.28	147.82	267.11	335.90	68.79	1.61	13.	5.0
3	1	39.10	109.48	147.82	257.31	401.35	144.04	3.68	11.	5.0
	2	53.10	169.92	147.82	317.74	401.35	83.60	1.57	11.	5.0
	3	47.60	152.32	54.00	206.32	401.35	195.03	4.10	11.	5.0
	4	36.60	102.48	147.82	250.31	401.35	151.04	4.13	11.	5.0
4	1	47.31	132.48	147.82	280.30	358.25	77.95	1.65	10.	5.0
	2	37.31	119.40	147.82	267.23	358.25	91.02	2.44	10.	5.0
	3	55.81	178.60	54.00	232.60	358.25	125.65	2.25	10.	5.0
	4	40.81	114.28	147.82	262.10	358.25	96.15	2.36	10.	5.0
5	1	33.45	93.67	147.82	241.49	323.90	82.41	2.46	10.	5.0
	2	64.97	207.89	147.82	355.72	4388.30	4032.58	62.07	10.	5.0
	3	27.45	87.85	54.00	141.85	323.90	182.05	6.63	10.	5.0
	4	28.45	79.67	147.82	227.49	323.90	96.41	3.39	10.	5.0
6	1	57.05	159.74	299.79	459.53	287.05	-172.48	-3.02	11.	5.0
	2	41.55	132.96	244.05	377.00	287.05	-89.95	-2.16	11.	5.0
	3	37.55	120.16	99.02	219.18	287.05	67.87	1.81	11.	5.0
	4	38.05	106.54	247.24	353.78	287.05	-66.73	-1.75	11.	5.0
7	1	47.75	133.70	285.65	419.35	535.90	116.55	2.44	11.	5.0
	2	46.86	149.95	285.65	435.60	513.60	78.00	1.66	11.	5.0
	3	43.53	139.29	140.63	279.91	455.30	175.39	4.03	11.	5.0
	4	35.45	99.26	243.02	342.29	415.90	73.61	2.08	11.	5.0
8	1	33.06	92.57	191.82	284.39	409.85	125.46	3.80	13.	5.0
	2	68.06	217.79	194.82	412.61	409.85	-2.76	-0.04	13.	5.0
	3	53.56	171.39	54.00	225.39	409.85	184.46	3.44	13.	5.0
	4	52.06	145.77	147.82	293.59	409.85	116.26	2.23	13.	5.0
9	1	46.76	130.92	147.82	278.75	375.75	97.00	2.07	13.	5.0
	2	40.76	130.43	147.82	278.25	375.75	97.50	2.39	13.	5.0
	3	45.26	144.83	54.00	198.83	375.75	176.92	3.91	13.	5.0
	4	44.26	123.92	147.82	271.75	375.75	104.00	2.35	13.	5.0
10	1	36.09	101.05	147.82	248.87	326.40	77.53	2.15	11.	5.0
	2	50.09	160.28	147.82	308.11	326.40	18.29	0.37	11.	5.0
	3	44.59	142.68	54.00	196.68	326.40	129.72	2.91	11.	5.0
	4	33.59	94.05	147.82	241.87	326.40	84.53	2.52	11.	5.0
11	1	44.09	123.45	142.82	266.28	278.55	12.27	0.28	9.	5.0
	2	34.09	109.09	142.82	251.91	278.55	26.64	0.78	9.	5.0
	3	52.59	168.29	49.00	217.29	278.55	61.26	1.16	9.	5.0
	4	37.59	105.25	142.82	248.08	278.55	30.47	0.81	9.	5.0
12	1	30.65	85.81	142.82	228.64	255.50	26.86	0.88	9.	5.0
	2	61.27	196.06	142.82	338.88	4297.60	3958.72	64.61	9.	5.0
	3	22.42	71.75	91.63	163.38	174.90	11.52	0.51	9.	5.0
	4	13.35	37.37	100.20	137.57	135.50	-2.07	-0.16	9.	5.0

! O V E R A L L   S U M M A R Y !

Sum of Net Present Value = T$ 6187.18 at a Discount Rate of 0.00%
The amortized values are T$ 737.99 per year,
or T$ 180.49 per season.
Total Labour Use over the whole time period is 2049.79 Labour days
The average ANNUAL labour use is 170.82 labour days,
and the average SEASONAL labour use is 42.70 labour days.
SNPV per Labour day = T$ 3.02
and SNPV per Land Use Factor = T$ 7279.04

CROP: TONGA INTERCROPPING 6 AREA UNIT: hectare

SUMMARY RESULTS

	SEASON	TOTAL LABOUR (DAYS)	VARIABLE COSTS: LABOUR COSTS (T$)	VARIABLE COSTS: MATERIAL COSTS (T$)	VARIABLE COSTS: TOTAL COSTS (T$)	GROSS REVENUE (T$)	NET REVENUE (T$)	N.R./LABOUR DAY (T$)	OUTPUT (100NUT)	PRICE (T$)
1	1	88.24	247.07	737.15	984.22	60.00	-924.22	-10.47	12.	5.00
	2	34.24	109.57	120.50	230.07	60.00	-170.07	-4.97	12.	5.00
	3	26.24	83.97	112.75	196.72	60.00	-136.72	-5.21	12.	5.00
	4	81.17	227.27	705.00	932.27	4124.40	3192.13	39.33	12.	5.00
2	1	47.38	132.65	300.75	433.40	62.50	-370.90	-7.83	13.	5.00
	2	28.38	90.80	120.50	211.30	62.50	-148.80	-5.24	13.	5.00
	3	12.38	39.60	112.75	152.35	62.50	-89.85	-7.26	13.	5.00
	4	34.80	97.45	505.00	602.45	1541.80	939.35	26.99	13.	5.00
3	1	41.92	117.36	125.00	242.36	54.00	-188.36	-4.49	11.	5.00
	2	24.92	79.73	5.00	84.73	54.00	-30.73	-1.23	11.	5.00
	3	10.92	34.93	5.00	39.93	54.00	14.07	1.29	11.	5.00
	4	36.38	101.87	185.00	286.87	1488.80	1201.93	33.04	11.	5.00
4	1	53.67	150.28	103.00	253.28	49.50	-203.78	-3.80	10.	5.00
	2	20.67	66.15	5.00	71.15	49.50	-21.65	-1.05	10.	5.00
	3	10.67	34.15	5.00	39.15	49.50	10.35	0.97	10.	5.00
	4	51.64	144.60	30.00	174.60	1573.60	1399.00	27.09	10.	5.00
5	1	6.73	18.84	5.00	23.84	50.50	26.66	3.96	10.	5.00
	2	6.73	21.53	5.00	26.53	50.50	23.97	3.56	10.	5.00
	3	6.73	21.53	5.00	26.53	50.50	23.97	3.56	10.	5.00
	4	6.73	18.84	5.00	23.84	50.50	26.66	3.96	10.	5.00
6	1	67.00	187.59	318.94	506.53	55.50	-451.03	-6.73	11.	5.00
	2	36.00	115.19	207.44	322.63	55.50	-267.13	-7.42	11.	5.00
	3	30.00	95.99	105.04	201.03	55.50	-145.53	-4.85	11.	5.00
	4	29.00	81.19	213.84	295.03	55.50	-239.53	-8.26	11.	5.00
7	1	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.00
	2	49.50	158.39	290.65	449.04	599.30	150.26	3.04	11.	5.00
	3	47.50	151.99	103.00	254.99	599.30	344.31	7.25	11.	5.00
	4	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.00
8	1	55.95	156.67	290.65	447.32	757.20	309.88	5.54	13.	5.00
	2	55.95	179.05	290.65	469.70	757.20	287.50	5.14	13.	5.00
	3	53.95	172.65	103.00	275.65	757.20	481.55	8.93	13.	5.00
	4	55.95	156.67	290.65	447.32	757.20	309.88	5.54	13.	5.00
9	1	53.11	148.70	290.65	439.35	684.50	245.15	4.62	13.	5.00
	2	53.11	169.95	290.65	460.60	684.50	223.90	4.22	13.	5.00
	3	51.11	163.55	103.00	266.55	684.50	417.95	8.18	13.	5.00
	4	53.11	148.70	290.65	439.35	684.50	245.15	4.62	13.	5.00
10	1	49.52	138.67	290.65	429.32	599.80	170.48	3.44	11.	5.00
	2	49.52	158.48	290.65	449.13	599.80	150.67	3.04	11.	5.00
	3	47.52	152.08	103.00	255.08	599.80	344.72	7.25	11.	5.00
	4	49.52	138.67	290.65	429.32	599.80	170.48	3.44	11.	5.00
11	1	45.85	128.39	280.65	409.04	510.10	101.06	2.20	9.	5.00
	2	45.85	146.73	280.65	427.38	510.10	82.72	1.80	9.	5.00
	3	43.85	140.33	93.00	233.33	510.10	276.77	6.31	9.	5.00
	4	45.85	128.39	280.65	409.04	510.10	101.06	2.20	9.	5.00
12	1	44.05	123.33	280.65	403.98	465.50	61.52	1.40	9.	5.00
	2	42.26	135.24	280.65	415.89	420.90	5.01	0.12	9.	5.00
	3	37.60	120.32	178.25	298.57	304.30	5.73	0.15	9.	5.00
	4	19.45	54.45	195.40	249.85	225.50	-24.35	-1.25	9.	5.00

! OVERALL SUMMARY !

Sum of Net Present Value = T$ 6247.63 at a Discount Rate of 6.00%
The amortized values are T$ 745.20 per year,
or T$ 182.25 per season.
Total Labour Use over the whole time period is 1941.60 Labour days
The average ANNUAL labour use is 161.80 labour days,
and the average SEASONAL labour use is 40.45 labour days.
SNPV per Labour day = T$ 3.22
and SNPV per Land Use Factor = T$ 6576.45

CROP: TONGA INTERCROPPING 7 AREA UNIT: Hectare

SUMMARY RESULTS

YEAR	SEASON	TOTAL LABOUR (DAYS)	* VARIABLE COSTS * LABOUR COSTS (T$)	MATERIAL COSTS (T$)	TOTAL COSTS (T$)	GROSS REVENUE (T$)	NET REVENUE (T$)	N.R./LABOUR DAY (T$)	OUTPUT (100NUT)	PRIC (T$
1	1	88.24	247.07	737.15	984.22	60.00	-924.22	-10.47	12.	5.0
	2	34.24	109.57	120.50	230.07	60.00	-170.07	-4.97	12.	5.0
	3	26.24	83.97	112.75	196.72	60.00	-136.72	-5.21	12.	5.0
	4	81.17	227.27	705.00	932.27	4124.40	3192.13	39.33	12.	5.0
2	1	60.38	169.05	404.73	573.78	62.50	-511.28	-8.47	13.	5.0
	2	32.90	105.29	487.68	592.97	1443.60	850.63	25.85	13.	5.0
	3	60.38	193.20	404.73	597.93	62.50	-535.43	-8.87	13.	5.0
	4	32.90	92.13	387.68	479.81	1443.60	963.79	29.29	13.	5.0
3	1	41.92	117.36	125.00	242.36	54.00	-188.36	-4.49	11.	5.0
	2	24.92	79.73	5.00	84.73	54.00	-30.73	-1.23	11.	5.0
	3	10.92	34.93	5.00	39.93	54.00	14.07	1.29	11.	5.0
	4	36.38	101.87	185.00	286.87	1488.80	1201.93	33.04	11.	5.0
4	1	53.67	150.28	103.00	253.28	49.50	-203.78	-3.80	10.	5.0
	2	20.67	66.15	5.00	71.15	49.50	-21.65	-1.05	10.	5.0
	3	10.67	34.15	5.00	39.15	49.50	10.35	0.97	10.	5.0
	4	51.64	144.60	30.00	174.60	1573.60	1399.00	27.09	10.	5.0
5	1	6.73	18.84	5.00	23.84	50.50	26.66	3.96	10.	5.0
	2	6.73	21.53	5.00	26.53	50.50	23.97	3.56	10.	5.0
	3	6.73	21.53	5.00	26.53	50.50	23.97	3.56	10.	5.0
	4	6.73	18.84	5.00	23.84	50.50	26.66	3.96	10.	5.0
6	1	67.00	187.59	318.94	506.53	55.50	-451.03	-6.73	11.	5.0
	2	36.00	115.19	207.44	322.63	55.50	-267.13	-7.42	11.	5.0
	3	30.00	95.99	105.04	201.03	55.50	-145.53	-4.85	11.	5.0
	4	29.00	81.19	213.84	295.03	55.50	-239.53	-8.26	11.	5.0
7	1	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.0
	2	49.50	158.39	290.65	449.04	599.30	150.26	3.04	11.	5.0
	3	47.50	151.99	103.00	254.99	599.30	344.31	7.25	11.	5.0
	4	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.0
8	1	55.95	156.67	290.65	447.32	757.20	309.88	5.54	13.	5.0
	2	55.95	179.05	290.65	469.70	757.20	287.50	5.14	13.	5.0
	3	53.95	172.65	103.00	275.65	757.20	481.55	8.93	13.	5.0
	4	55.95	156.67	290.65	447.32	757.20	309.88	5.54	13.	5.0
9	1	53.11	148.70	290.65	439.35	684.50	245.15	4.62	13.	5.0
	2	53.11	169.95	290.65	460.60	684.50	223.90	4.22	13.	5.0
	3	51.11	163.55	103.00	266.55	684.50	417.95	8.18	13.	5.0
	4	53.11	148.70	290.65	439.35	684.50	245.15	4.62	13.	5.0
10	1	49.52	138.67	290.65	429.32	599.80	170.48	3.44	11.	5.0
	2	49.52	158.48	290.65	449.13	599.80	150.67	3.04	11.	5.0
	3	47.52	152.08	103.00	255.08	599.80	344.72	7.25	11.	5.0
	4	49.52	138.67	290.65	429.32	599.80	170.48	3.44	11.	5.0
11	1	45.85	128.39	280.65	409.04	510.10	101.06	2.20	9.	5.0
	2	45.85	146.73	280.65	427.38	510.10	82.72	1.80	9.	5.0
	3	43.85	140.33	93.00	233.33	510.10	276.77	6.31	9.	5.0
	4	45.85	128.39	280.65	409.04	510.10	101.06	2.20	9.	5.0
12	1	44.05	123.33	280.65	403.98	465.50	61.52	1.40	9.	5.0
	2	42.26	135.24	280.65	415.89	420.90	5.01	0.12	9.	5.0
	3	37.60	120.32	178.25	298.57	304.30	5.73	0.15	9.	5.0
	4	19.45	54.45	195.40	249.85	225.50	-24.35	-1.25	9.	5.0

! OVERALL SUMMARY !

Sum of Net Present Value = T$ 6652.26 at a Discount Rate of 6.00%
The amortized values are T$ 793.46 per year,
or T$ 194.05 per season.
Total Labour Use over the whole time period is 2005.22 Labour days
The average ANNUAL labour use is 167.10 labour days,
and the average SEASONAL labour use is 41.78 labour days.
SNPV per Labour day = T$ 3.32
and SNPV per Land Use Factor = T$ 7002.38

CROP: TONGA INTERCROPPING 8 AREA UNIT: Hectare

SUMMARY RESULTS

YEAR	SEASON	TOTAL LABOUR (DAYS)	VARIABLE COSTS: LABOUR COSTS (T$)	VARIABLE COSTS: MATERIAL COSTS (T$)	VARIABLE COSTS: TOTAL COSTS (T$)	GROSS REVENUE (T$)	NET REVENUE (T$)	N.R./ LABOUR DAY (T$)	OUTPUT (100NUT)	PRICE (T$)
1	1	88.24	247.07	737.15	984.22	60.00	-924.22	-10.47	12.	5.0
	2	34.24	109.57	120.50	230.07	60.00	-170.07	-4.97	12.	5.0
	3	26.24	83.97	112.75	196.72	60.00	-136.72	-5.21	12.	5.0
	4	81.17	227.27	705.00	932.27	4124.40	3192.13	39.33	12.	5.0
2	1	47.38	132.65	300.75	433.40	62.50	-370.90	-7.83	13.	5.0
	2	28.38	90.80	120.50	211.30	62.50	-148.80	-5.24	13.	5.0
	3	12.38	39.60	112.75	152.35	62.50	-89.85	-7.26	13.	5.0
	4	34.80	97.45	505.00	602.45	1541.80	939.35	26.99	13.	5.0
3	1	59.92	167.76	304.73	472.50	54.00	-418.50	-6.98	11.	5.0
	2	32.44	103.82	387.68	491.50	1435.10	943.60	29.08	11.	5.0
	3	59.92	191.73	304.73	496.46	54.00	-442.46	-7.38	11.	5.0
	4	32.44	90.84	387.68	478.52	1435.10	956.58	29.48	11.	5.0
4	1	53.67	150.28	103.00	253.28	49.50	-203.78	-3.80	10.	5.0
	2	20.67	66.15	5.00	71.15	49.50	-21.65	-1.05	10.	5.0
	3	10.67	34.15	5.00	39.15	49.50	10.35	0.97	10.	5.0
	4	51.64	144.60	30.00	174.60	1573.60	1399.00	27.09	10.	5.0
5	1	6.73	18.84	5.00	23.84	50.50	26.66	3.96	10.	5.0
	2	6.73	21.53	5.00	26.53	50.50	23.97	3.56	10.	5.0
	3	6.73	21.53	5.00	26.53	50.50	23.97	3.56	10.	5.0
	4	6.73	18.84	5.00	23.84	50.50	26.66	3.96	10.	5.0
6	1	67.00	187.59	318.94	506.53	55.50	-451.03	-6.73	11.	5.0
	2	36.00	115.19	207.44	322.63	55.50	-267.13	-7.42	11.	5.0
	3	30.00	95.99	105.04	201.03	55.50	-145.53	-4.85	11.	5.0
	4	29.00	81.19	213.84	295.03	55.50	-239.53	-8.26	11.	5.0
7	1	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.0
	2	49.50	158.39	290.65	449.04	599.30	150.26	3.04	11.	5.0
	3	47.50	151.99	103.00	254.99	599.30	344.31	7.25	11.	5.0
	4	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.0
8	1	55.95	156.67	290.65	447.32	757.20	309.88	5.54	13.	5.0
	2	55.95	179.05	290.65	469.70	757.20	287.50	5.14	13.	5.0
	3	53.95	172.65	103.00	275.65	757.20	481.55	8.93	13.	5.0
	4	55.95	156.67	290.65	447.32	757.20	309.88	5.54	13.	5.0
9	1	53.11	148.70	290.65	439.35	684.50	245.15	4.62	13.	5.0
	2	53.11	169.95	290.65	460.60	684.50	223.90	4.22	13.	5.0
	3	51.11	163.55	103.00	266.55	684.50	417.95	8.18	13.	5.0
	4	53.11	148.70	290.65	439.35	684.50	245.15	4.62	13.	5.0
10	1	49.52	138.67	290.65	429.32	599.80	170.48	3.44	11.	5.0
	2	49.52	158.48	290.65	449.13	599.80	150.67	3.04	11.	5.0
	3	47.52	152.08	103.00	255.08	599.80	344.72	7.25	11.	5.0
	4	49.52	138.67	290.65	429.32	599.80	170.48	3.44	11.	5.0
11	1	45.85	128.39	280.65	409.04	510.10	101.06	2.20	9.	5.0
	2	45.85	146.73	280.65	427.38	510.10	82.72	1.80	9.	5.0
	3	43.85	140.33	93.00	233.33	510.10	276.77	6.31	9.	5.0
	4	45.85	128.39	280.65	409.04	510.10	101.06	2.20	9.	5.0
12	1	44.05	123.33	280.65	403.98	465.50	61.52	1.40	9.	5.0
	2	42.26	135.24	280.65	415.89	420.90	5.01	0.12	9.	5.0
	3	37.60	120.32	178.25	298.57	304.30	5.73	0.15	9.	5.0
	4	19.45	54.45	195.40	249.85	225.50	-24.35	-1.25	9.	5.0

! O V E R A L L S U M M A R Y !

Sum of Net Present Value = T$ 6293.09 at a Discount Rate of 6.00%
The amortized values are T$ 750.62 per year,
or T$ 183.57 per season.
Total Labour Use over the whole time period is 2012.18 Labour days
The average ANNUAL labour use is 167.68 labour days,
and the average SEASONAL labour use is 41.92 labour days.
SNPV per Labour day = T$ 3.13
and SNPV per Land Use Factor = T$ 6624.30

CROP: TONGA INTERCROPPING 9 AREA UNIT: Hectar

! S U M M A R Y R E S U L T S !

YEAR	SEASON	TOTAL LABOUR (DAYS)	* V A R I A B L E C O S T S * LABOUR COSTS (T$)	MATERIAL COSTS (T$)	TOTAL COSTS (T$)	GROSS REV-ENUE (T$)	NET REVENUE (T$)	N.R./ LABOUR DAY (T$)	OUTPUT (100NUT)	P R I C (T$
1	1	88.24	247.07	737.15	984.22	60.00	-924.22	-10.47	12.	5.0
	2	34.24	109.57	120.50	230.07	60.00	-170.07	-4.97	12.	5.0
	3	26.24	83.97	112.75	196.72	60.00	-136.72	-5.21	12.	5.0
	4	81.17	227.27	705.00	932.27	4124.40	3192.13	39.33	12.	5.0
2	1	47.38	132.65	300.75	433.40	62.50	-370.90	-7.83	13.	5.0
	2	28.38	90.80	120.50	211.30	62.50	-148.80	-5.24	13.	5.0
	3	12.38	39.60	112.75	152.35	62.50	-89.85	-7.26	13.	5.0
	4	34.80	97.45	505.00	602.45	1541.80	939.35	26.99	13.	5.0
3	1	41.92	117.36	125.00	242.36	54.00	-188.36	-4.49	11.	5.0
	2	24.92	79.73	5.00	84.73	54.00	-30.73	-1.23	11.	5.0
	3	10.92	34.93	5.00	39.93	54.00	14.07	1.29	11.	5.0
	4	36.38	101.87	185.00	286.87	1488.80	1201.93	33.04	11.	5.0
4	1	59.67	167.08	304.73	471.82	49.50	-422.32	-7.08	10.	5.0
	2	32.20	103.04	387.68	490.72	1430.60	939.88	29.19	10.	5.0
	3	59.67	190.95	304.73	495.69	49.50	-446.19	-7.48	10.	5.0
	4	32.20	90.16	387.68	477.84	1430.60	952.76	29.59	10.	5.0
5	1	6.73	18.84	5.00	23.84	50.50	26.66	3.96	10.	5.0
	2	6.73	21.53	5.00	26.53	50.50	23.97	3.56	10.	5.0
	3	6.73	21.53	5.00	26.53	50.50	23.97	3.56	10.	5.0
	4	6.73	18.84	5.00	23.84	50.50	26.66	3.96	10.	5.0
6	1	67.00	187.59	318.94	506.53	55.50	-451.03	-6.73	11.	5.0
	2	36.00	115.19	207.44	322.63	55.50	-267.13	-7.42	11.	5.0
	3	30.00	95.99	105.04	201.03	55.50	-145.53	-4.85	11.	5.0
	4	29.00	81.19	213.84	295.03	55.50	-239.53	-8.26	11.	5.0
7	1	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.0
	2	49.50	158.39	290.65	449.04	599.30	150.26	3.04	11.	5.0
	3	47.50	151.99	103.00	254.99	599.30	344.31	7.25	11.	5.0
	4	49.50	138.59	290.65	429.24	599.30	170.06	3.44	11.	5.0
8	1	55.95	156.67	290.65	447.32	757.20	309.88	5.54	13.	5.0
	2	55.95	179.05	290.65	469.70	757.20	287.50	5.14	13.	5.0
	3	53.95	172.65	103.00	275.65	757.20	481.55	8.93	13.	5.0
	4	55.95	156.67	290.65	447.32	757.20	309.88	5.54	13.	5.0
9	1	53.11	148.70	290.65	439.35	684.50	245.15	4.62	13.	5.0
	2	53.11	169.95	290.65	460.60	684.50	223.90	4.22	13.	5.0
	3	51.11	163.55	103.00	266.55	684.50	417.95	8.18	13.	5.0
	4	53.11	148.70	290.65	439.35	684.50	245.15	4.62	13.	5.0
10	1	49.52	138.67	290.65	429.32	599.80	170.48	3.44	11.	5.0
	2	49.52	158.48	290.65	449.13	599.80	150.67	3.04	11.	5.0
	3	47.52	152.08	103.00	255.08	599.80	344.72	7.25	11.	5.0
	4	49.52	138.67	290.65	429.32	599.80	170.48	3.44	11.	5.0
11	1	45.85	128.39	280.65	409.04	510.10	101.06	2.20	9.	5.0
	2	45.85	146.73	280.65	427.38	510.10	82.72	1.80	9.	5.0
	3	43.85	140.33	93.00	233.33	510.10	276.77	6.31	9.	5.0
	4	45.85	128.39	280.65	409.04	510.10	101.06	2.20	9.	5.0
12	1	44.05	123.33	280.65	403.98	465.50	61.52	1.40	9.	5.0
	2	42.26	135.24	280.65	415.89	420.90	5.01	0.12	9.	5.0
	3	37.60	120.32	178.25	298.57	304.30	5.73	0.15	9.	5.0
	4	19.45	54.45	195.40	249.85	225.50	-24.35	-1.25	9.	5.0

! O V E R A L L S U M M A R Y !

Sum of Net Present Value = T$ 6130.55 at a Discount Rate of 0.00%
The amortized values are T$ 731.23 per year,
or T$ 178.83 per season.
Total Labour Use over the whole time period is 1988.68 Labour days
The average ANNUAL labour use is 165.72 labour days,
and the average SEASONAL labour use is 41.43 labour days.
SNPV per Labour day = T$ 3.08
and SNPV per Land Use Factor = T$ 6453.21